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Transactions

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OF THE

Canadian Mining Institute

1910

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VOLUME XIII

"The Institute as a body shall not be responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at its meetings."—*By-Laws, Par. 48.*

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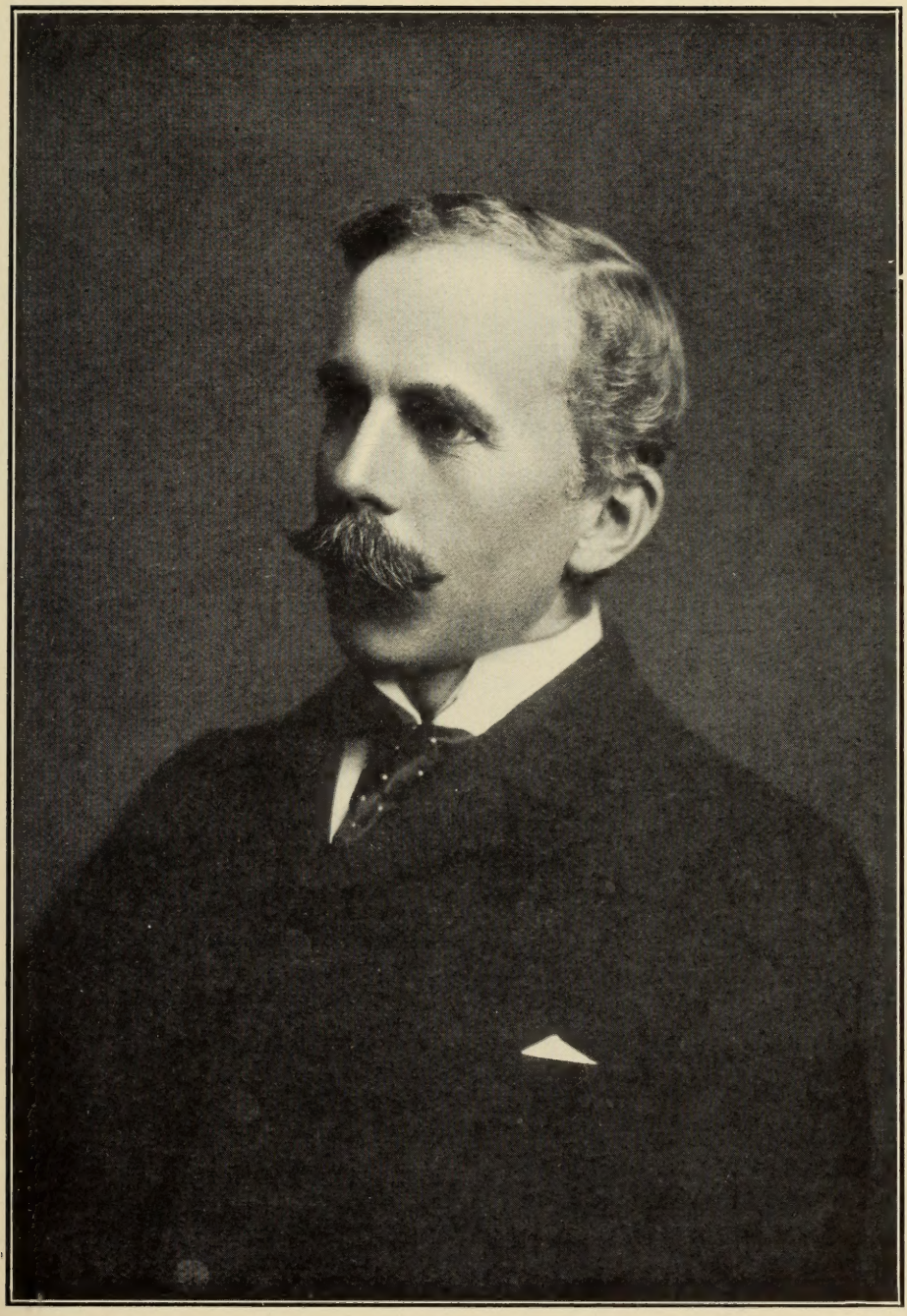

DR. FRANK D. ADAMS,

PRESIDENT OF THE CANADIAN MINING INSTITUTE, MARCH 1910—MARCH 1911

CANADIAN MINING INSTITUTE

List of Officers and Members of Council since the Establishment of the Institute showing the years during which office has been held.

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Hardman, J. E , 1898-99.
Keffer, Frederic, 1907.
Miller, Dr. W. G., 1908, 1909.
Smith, G. R., 1905, 1906.

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Chambers, R. E., 1903, 1904.
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Dawson, Dr. G. M., C.M.G., 1898 œœ
Dawson, Dr. G. M., C.M.G., 1898–99.
Donkin, Hiram, 1899, 1900.
Drummond, Geo. E., 1899, 1900, 1908, 1909.
Duggan, G. H., 1905, 1906, 1907.
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Goodwin, W. L., 1905.
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Blakemore, Wm., 1898–9.
Blaylock, S. G., 1910.
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Blue, John, 1905, 1906.
Brent, Charles, 1899, 1900.
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Browne, David H., 1907, 1908.
Bryce, R. A., 1910.
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Donnelly, J., 1909, 1910.
Dresser, J. A., 1910.
Drummond, Geo. E., 1898–9.
Drury, H. A., 1908, 1909.
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Fraser, Graham, 1904.
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Smith, J. Burley, 1900, 1901.
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Stewart, R. H., 1908, 1909.
Tonkin, J. H., 1903.
Turner, A. P., 1902, 1903.
Tyrrell, J. B., 1908, 1909, 1910.
Whiteside, O. E. S., 1910.
Williams, H. J., 1903, 1904, 1905, 1906.
Willmott, A. B., 1905.

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Bell, B. T. A., 1898, 1899, 1900, 1901, 1902, 1903.
Coste, Eugene (Acting Secretary), 1904.
Lamb, H. Mortimer, 1905, 1906, 1907, 1908, 1909, 1910.

TREASURER

Brown, J. Stevenson, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1907, 1908.
Lecky, W. S., 1909, 1910.
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MEETINGS

CANADIAN MINING INSTITUTE

PROCEEDINGS OF THE TWELFTH ANNUAL MEETING

TORONTO, March 2nd, 3rd, & 4th, 1910.

The Twelfth Annual General Meeting of the Institute was held at the King Edward Hotel, Toronto, on Wednesday, Thursday and Friday, March 2nd, 3rd, and 4th, 1910. The register was signed by two hundred and nineteen members and others, this constituting the largest attendance yet recorded at any meeting of the Institute.

WEDNESDAY MORNING SESSION.

The members having assembled in the Ball Room of the hotel, the proceedings were opened by the President, Dr. WILLET G. MILLER, at 10.30 a.m., who introduced to the meeting MR. ALDERMAN MCGUIRE, Chairman of the Reception Committee of the City. Mr. McGuire, on behalf of the Mayor and Corporation briefly but eloquently and cordially welcomed the Institute to Toronto.

THE PRESIDENT then delivered his annual address, as follows:

PRESIDENTIAL ADDRESS.

"Gentlemen,—It gives me pleasure to welcome you to this the twelfth annual meeting of the Canadian Mining Institute. On two former occasions, 1904 and 1907, we of Ontario have had the privilege of meeting our fellow members from other provinces at annual gatherings of the Institute in this, our capital city. Since the earlier of these meetings Toronto has become one of the important mining centres of the continent.

"While the Institute has a history of only twelve years—a period, however, of very notable development in the mining industries in this country,—its lineage can be traced some years

further back through its immediate predecessor, the Federated Institute, and those provincial mining societies by the coalescing of which the Federated Institute was formed.

"In my presidential address last year I gave a brief account of some of the work accomplished by the Institute. This year I propose to review briefly the progress of the mineral industry during the past year, as well as refer to recent important developments in Canada so far as they have affected or are likely to affect the industry. I shall also indicate what in my judgment are some of the main objects of the Institute and certain objects that we should aim in particular to achieve in the future.

Progress in 1909.—"The year, although not marked by any new developments of a specially sensational character, has been a period of steady and substantial industrial growth and activity. Nearly every year, however, sees the exploitation of new mining camps in Canada. Those to which chief attention was directed during 1909 were the alliterative twins—Porcupine and Portland Canal—the one on the Pacific coast and the other in the great central region. Perhaps the most striking feature of the past year has been the tendency on the part of large industrial concerns to consolidate their interests, which, provided the industries are not unduly handicapped by over-capitalization, should make for increased efficiency and economy in management and operation. This would especially apply in the case of the amalgamation of the coal and steel interests in Nova Scotia, which industries are largely interdependent. In Quebec, the amalgamation of the asbestos mines has at least served to stimulate mining activity throughout the Eastern Townships. In Alberta, as a result of railway construction, great activity has been displayed in connection with the acquisition and development of coal areas. In British Columbia good general progress has been made. The Ontario mineral output was the largest on record.

"Notwithstanding that the prices of metals generally have been somewhat lower than prices during 1908, the value of the mineral production for 1909 should represent an increase of from three to four million dollars. For this gain, Ontario is, I believe, chiefly responsible; although British Columbia is credited with an increased production of about a million dollars, and possibly the increased output of coal in Alberta will, to some extent, offset the

decrease in Nova Scotia, due to the protracted strike of coal miners in that Province.

"Canada has become less and less dependent on foreign smelters and refiners. The Granby copper smelter in British Columbia is now the largest in the British Empire. Very important work is being done at the refinery at Trail; while the plants erected during the last few years in Ontario—at Copper Cliff, Deloro and Thorold—have greatly advanced metallurgical work in this country.

"The Royal Mint at Ottawa is gradually increasing its usefulness. Heretofore it has been minting copper and silver coins and British sovereigns. Now the minting of Canadian gold is to be undertaken. It is to be hoped that ere long Canada will have a pure nickel coin, since this metal has been proved by its use in several European countries to be well adapted for coinage purposes. Surely the country that supplies the major part of the metal to commerce should have a representative nickel coinage.

"Of the four great industries in Canada—agriculture, mining, forestry and fisheries—dependent on development of our natural resources, mining stands second only to agriculture in point of value of annual production. The value of the output of our minerals is greater than that of forestry and fisheries combined.

Railways.—"It is said that about 65 per cent. of the freight carried by the railways of the United States represents minerals or mineral products. This is substantial enough evidence of the important relations existing between the mineral industry and the railways. It shows, moreover, how dependent one is on the other. Hence it is most encouraging having regard to the future expansion of the mining industry in Canada, to note that extensive railway construction is now being carried on and projected. Thus we are told the three great Canadian railway companies contemplate expending during the present year alone the enormous sum of sixty million dollars or over on the building of new lines or in providing double tracks. The building of these new lines is making and will make a vast territory accessible to the prospector and miner. The National Transcontinental, for example, in its course through the northern parts of the provinces of Ontario and Quebec, will double the area of accessible territory in both provinces. The

construction of the Grand Trunk Pacific will exert an equally beneficial influence on the development of northern British Columbia; while other lines are opening up, or will open up within a few years, vast areas throughout Canada.

"The Dominion Government has, it appears, now definitely decided that a railway shall be built to Nelson Harbour on Hudson Bay. The primary object in the construction of this road is to provide for the shipment of grain; but even if grain is never carried over the road, its building should be fully justified. Hudson Bay has an enormous extent of Coast line; it has many tributary rivers; and throughout the country thus made accessible to the prospector the character of the rocks is peculiarly favourable to the occurrence of mineral. Hence there is every likelihood of the establishment of an important mining industry in this area consequent upon railway construction. After the completion of the road Port Nelson will be brought within a day or so's journey from Winnipeg, and steamers will also navigate from Port Nelson to various localities on the Bay. This will, of course, provide for a relatively long season during which prospecting and exploring may be carried on. Important fisheries should also be established in these Northern waters.

"Again, another railway is likely to be built from Edmonton to Fort McMurray on the Mackenzie river waters. This will make the vast northern interior of Canada more accessible. The great territory along the Mackenzie and its tributaries and in the vicinity of the Great Slave and Great Bear Lakes is known to possess promising mineral occurrences; but under present conditions exploration is almost impossible.

"In brief, the situation having regard to the rapid extension of our railway systems is eminently encouraging, and as these extensions will result in the opening up of much new territory to the prospector, probably twice the area at present accessible to him, one may confidently anticipate to witness a remarkable expansion of the mineral industry of this country within the next few years.

Water Powers.—"In many parts of Canada, and especially in the great central region, the availability of water powers has had an important bearing on the mineral industry. This is evidenced by the use that has already been made of these powers in the greatest metalliferous areas that have as yet been developed—

those of the Boundary district of British Columbia and of Sudbury and Cobalt in Ontario. In British Columbia the plant at Bonnington Falls supplies power to the mines at Rossland, Phœnix and Greenwood and to the smelters at Trail, Grand Forks, Greenwood and Boundary Falls. In Ontario, the Canadian Copper Company has developed a water power that supplies with electric energy the large mines at Creighton and Crean Hill and the plant at Copper Cliff. Other mining companies in the Sudbury district—Victoria mines, North Nickel range and Moose mountain—are using or are preparing to use electric power generated by water falls. Power is now being delivered at Cobalt from the Montreal river and in a short time the camp will have an abundant supply from this river and from the Matabitchuan. The benefits derived in these great metal camps from the utilizatlon of water powers well illustrate the value of this source of energy to our industry. Without the results that electrical and mechanical engineers have achieved during recent years, this employment of power would not have been possible.

"But electricity has accomplished even greater things in other branches of the mineral industry during comparatively recent times. The inventions of Hall, Acheson, Willson and others in the production of metals and artificial minerals have made this age famous. Fifty years ago aluminum was little more than a scientific curiosity and sold for two dollars an ounce. During the last year it has sold as low as fifteen cents a pound and is one of the common metals of commerce and the arts. The production of carborundum and other artificial abrasives has done much to assist the manufacturers of machinery. Artificial graphite has become an important article of commerce. Artificial rubies are produced on a commercial scale. Various alloys, that are now considered necessary in metallurgical work, are due to recent advances in electrical knowledge. Calcium carbide, a product of the electric furnace, is used as a source of light. Again the employment of electricity in the refining of several metals and in the concentration of certain ores is worthy of comment. But the most recent commercial achievement in electro-chemistry, the fixation of the nitrogen of the air, is the one that appeals most strongly to the imagination; and it may confer wide, if at present unseen, benefits on our race. Certain compounds of nitrogen are essential as plant food.

A few plants possess the power of abstracting free nitrogen from the air; but the great majority are dependent on extraneous compounds for their food supply. The store of mineral nitrates, which have long been in demand as fertilizers, is limited. Recently electricity has come to the rescue of agriculture, and nitrogen is taken from the air and made into various compounds. Fifteen million dollars are already invested in works in Norway, where water powers are abundant as they are in our own country.

"While these remarks may appear commonplace, still they will now serve their purpose if they sufficiently emphasise the value of our water powers as a factor in mineral and industrial developments in Canada.

Forestry.—"Miners are sometimes accused of taking little interest in the preservation and the proper utilization of the forests. Since, however, mining cannot be effectively carried on if forest products at reasonable cost are not available, our mining community is essentially interested in seeing that forests are protected. Hence the present general movement in Canada for the protection of forests and afforestation will necessarily receive the support of those associated with the mineral industry.

Mining Legislation.—"Our secretary is to present a paper at this meeting dealing with mining laws and regulations. In this paper the regulations of various countries governing the disposition of mineral lands are compared and discussed. Ideal regulations, however, will probably never be framed by any state. In all mining legislation the interests of two distinct classes as represented by respectively the poor man or prospector on the one hand, and the capitalist on the other, must be considered. If the development of industry is alone regarded, and the principle of encouraging individual effort altogether ignored, then the mining laws of Mexico, for example, are nearly ideal. In brief, the mining law of Mexico enables individuals or companies to acquire areas from the government and to retain possession of them so long as they continue to pay regularly the annual acreage tax thereon. Of course this acreage tax would under conditions obtaining in Canada often work a hardship on the poor man and would make it difficult for anyone but a wealthy individual or company to hold land. The tendency is, when laws are made with the object of conserving both the rights of the prospector and the rights of the capi-

talist, for confusion to arise. The weaknesses in the mining laws of the various provinces of Canada are due to this. If it were only necessary to consider one class, it would be possible to greatly simplify the laws. For instance, in some of the provinces of Canada and in some of the states of the Union working conditions are exacted from the holders of mineral lands in lieu of an annual tax as in Mexico. It is considered easier for the man without capital to do each year so much work than to pay an annual tax. Working conditions are also believed to tend to the more rapid development of an industry; but in my opinion working conditions have never been very successful in any state or province in North America. In fact, the insistence on work frequently leads to fraud.

"The mining laws of British Columbia and Ontario have, owing to the development of the metallic industries during recent years, attracted more attention than those of the other provinces. It has been found that, in both provinces, one of the great weaknesses is blanketing. This is due largely to permission to stake by proxy. A man is not only permitted to stake two, three or more claims on his own license but, by getting licenses in the names of his sisters, aunts and other individuals, he may stake *ad infinitum*. One would think that if a man succeeded in staking say three good claims in a year he should be satisfied. Some people, however, seem to think that a prospector is capable of staking many more good claims in one season; hence he has been given great latitude. Moreover, staking by proxy often reacts against the interests of legitimate prospectors. So many claims are offered for sale that prices are lowered and there is difficulty in separating the wheat from the chaff. British Columbia has an acreage tax which is good in so far as it goes, and Ontario imposes a small tax on claims in unorganized territory; but the effects brought about by this acreage tax in these provinces are not nearly so far-reaching as the effect produced by Mexico's heavier impost. An acreage tax is the best preventive of blanketing and the tying up of mineral lands.

"Another point which is often discussed is whether governments should dispose of lands in fee simple or under lease. In Mexico for instance, the leasing system is practically universal. Here it does not appear to have injuriously affected industry. Large foreign companies are constantly starting undertakings in Mexico. In some of the provinces of Canada, however, great objection has

been raised to the principle of leasehold. It has been claimed that it is often impossible to raise money on property which is not held in fee simple.

"The Quebec Act was amended in 1909, the law as then amended becoming operative at the beginning of this year. The regulations seem to me to be well adapted to the existing conditions in the Province of Quebec. While of course they cannot be regarded as ideal, with very slight further modifications they would be about as good as could be expected. Thus the price per acre ranging from $10 to $20, according to distance from a railway, is higher than that charged in any other country. In fact it would seem to be too high, for the reason that the Government is likely to receive less revenue than if a lower price had been specified. Again, to some extent this regulation will have a tendency to discourage poor men. Then, since there is no intention, as I understand, on the part of the Quebec authorities of inspecting "discoveries," it seems to me that "discovery" should not be included among the requirements in the case of those making application for mineral lands. This requirement will serve no useful purpose and may lead to trouble in certain cases.

"In passing, I should like to remark, and in this I feel I am expressing the opinion of all who know Mr. T. Denis or his work, that that gentleman's recent appointment as Superintendent of Mines for Quebec has given very great general satisfaction. The Government is to be congratulated upon its choice.

"During the past year the Dominion Government has done much to encourage the industry. The appointment of the Select Standing Committee on Mines and Minerals was a move in the right direction. Hereafter the mineral industry will no doubt receive still greater recognition. As a result of their last session's labours the Committee recommended that the Government enact a code of mining regulations applicable to Dominion lands. The Committee were strongly of the opinion that the present method of dealing with these lands by Orders-in-Council should be done away with. It is to be hoped that action will be taken on this recommendation of the Committee in the near future. The mining community in general will agree that a code of mining laws applicable to Dominion lands is most desirable. The Committee further recommended that the management of the Dominion mining lands

should be transferred from the Department of the Interior to the Department of Mines.

"The Dominion Government has also appointed during the past year a National Conservation Commission. This Commission should have a wide field of usefulness. Unfortunately, when new subjects come up, or old subjects under new names such as that of "Conservation," faddists not infrequently become active—and it takes time to get on a solid foundation. This has been to some extent the case with forestry and with our own industry. This Institute and organizations of like character in other countries have, it seems to me, been dealing effectively with conservation problems in the past and, in so far as the mineral industry is concerned, the Institute will continue to be the organization in this country the most competent to give advice on such problems. The membership of the Institute includes many men to whom the prevention of accidents, the refining of ores so as to prevent waste, and all the other problems connected with the industry have been subjects of life long study. There are some subjects with which governments can give assistance, and their assistance is always welcomed; but the mineral industry is one that does not flourish under paternalism, and advice such as has sometimes been offered in this country is not welcomed.

"How small a part of all that we endure
"Is that which governments can cause or cure.

"The prevention of mine accidents is a subject that has received careful attention in Canada. With regard to the inspection of the metal mines of Ontario, with which I happen to be familiar, I may say that I do not know of any metal mining state in the Union where mine inspection has been more systematically undertaken. Accidents will always be more numerous where there are many small mines or prospects than where the same number of men are employed in a few large mines. The inspections (including analyses and other tests) of explosives, is a subject with which mine managers cannot be expected to deal. It also offers a field of work for the Government.

"Changes are needed in connection with sanitary regulations for new mining camps. Many mining men feel that these new camps should not at first be organized on municipal lines, but that they should be governed by commission. Sanitary precautions

could be taken from the beginning and money raised by taxation could be expended with better results than it usually is by municipal officers in the hurly-burly period of a camp's existence.

"As regards the prevention of waste in the handling and refining of ores, I think it can be said without fear of contradiction that Canadian metallurgists are fully alive to the subject. I do not think that a government can lead the way for private metallurgists.

"The Dominion Government has apparently decided to appoint a Commission to deal with technical education. This subject all miners will admit has a very important bearing on their industry. The Government is to be congratulated on its decision. It has been suggested for some years that technical education, being so closely connected with trade and commerce, should be dealt with by the Dominion Government, although education is, by the British North America Act, left to the jurisdiction of the various provinces. It is to be hoped that the broader view will prevail, and that the Dominion Government will see its way to assist very materially in the work of technical education.

"There has been a great change of opinion respecting education in Canada during the last twenty years or so. Most of us will remember that in our college days the type of education prescribed was that which had been found to be a success especially in Britain. This educational system was transplanted bodily to Canada and was supposed to be adapted to the needs of a country so different from Britain. Fortunately during the last couple of decades, scientific and technical education has received much more attention, and it is now considered by many that a man with a technical knowledge can be of as much service to his country as can one who has pursued merely one of the older courses of learning. Former ages have excelled the present in art and literature; but the present stands pre-eminent in the utilization of the forces of nature for the comfort and happiness of mankind.

Mining Taxation.—"I have referred under mining laws to one kind of mining taxation, namely, the acreage tax. A majority of those engaged in mining will agree that this form of taxation exercises beneficial results on the industry, in that it tends to keep titles clear and to prevent the tying up of lands by speculators.

It can, I think, be said to be an unique tax, since I never heard of another that was welcomed by those who had to pay it!

"While those engaged in the mineral industry are desirous of bearing their fair share of the expenses of government, they frequently feel that they are unjustly discriminated against. If a mine or metallurgical works have a large equipment, or if the profits are even moderately large, the cupidity of those not connected with the industry is sometimes aroused and there is a tendency to levy disproportionate taxes on the mine or works.

"There are broadly two methods of taxing output, viz, on the gross or on the net profits. A tax on gross output is rarely fair. No consideration is given to costs of production. A tax on profits is much more equitable.

"But the point in connection with mine taxation requiring chief consideration is that which concerns the capital itself. If the net earnings of a mine are taxed at the same rate as ordinary income, the tax can be shown to be unfair to the mine owners, since the net earnings of a mine represent to a large extent capital. As ore is taken from a mine from year to year the property becomes constantly less valuable until finally, when the ore has all been mined, the property is valueless. It is easy, therefore, to show that the net income from a mine should not be taxed on the same basis as income derived from other sources. This phase of taxation of mines is now receiving considerable attention in certain parts of the United States.

Our Mines Abroad.—"No country has larger, undeveloped, promising mineral fields than Canada. It is important, therefore, if the mineral industry in this country is to make the progress it should, that capital be available. Heretofore most of the capital invested in mining enterprises has been furnished by Canadians themselves or by the people of the United States. If one reads the mining journals and the transactions of technical societies in Great Britain, he must necessarily be struck by the fact of the scant attention given in the mother country to Canada's industry. Pages are devoted to the industry of Australia and Africa, while references to Canada will be dismissed with a line or at most a paragraph or two.

"It was chiefly with the object of making the mineral resources of this country better known in Britain and on the continent

that the Canadian Mining Institute, with the assistance of the Dominion and the Provincial Governments, organized the trans-Canada excursion of 1908. Sufficient time has now elapsed to determine some of the results of the excursion. Not to enter into details I may say that the results have been all that could be desired. Some important investments of capital have been made and several Canadian mining engineers have been asked to make reports on properties by British investors. During the excursion leading mining engineers from abroad had the opportunity of visiting our mining camps and of making the acquaintance of their Canadian confrères. Very cordial relations now exist between a number of mining societies in Britain, notably the Institution of Mining and Metallurgy, and the Canadian Mining Institute.

"It seems to me that no more important work can be done by this Institute than that of making the mineral resources of the country better known in Great Britain and of encouraging the interchange of views between the technical men on the two sides of the Atlantic.

The Future of the Institute.—"When we consider the good work the Institute has been able to accomplish in the past we may well believe that it will continue in the future to serve a no less useful purpose. It can be said, I think, that the Institute's influence has been exerted on broad lines with the view to promoting the development of the mining industry in our own country, as well as of advancing the science and art of mining generally.

"The members have been encouraged in their work by the recognition that has been extended to the Institute. One recognition that we have had is the acceptance of invitations to our annual meetings by distinguished fellow workers in the United States. I can assure those gentlemen from the great republic who have honoured us by attending this annual meeting that their presence here is most highly appreciated and that it affords us much encouragement.

"As my presidency of the Institute terminates at the close of this annual meeting I may be permitted to say that I trust the policy of the Institute will be the same in the future as it has been in the past. The field of work is vast. One-third of a continent awaits development.

For my successor in the presidency I can hope for nothing better than that his term of office shall be as pleasant as has been mine." (Applause.)

THE NATIONAL COMMISSION OF CONSERVATION.

Mr. BRIGSTOCKE:—"Mr. President, I have a resolution I wish to submit to this meeting. It has reference to certain remarks in your address anent the Conservation Commission lately appointed by the Federal Government. My resolution reads as follows:—

"RESOLVED:—That the Canadian Mining Institute regret that the Chairman of the Conservation Committee should have publicly made statements reflecting on the mining and metallurgical practice of Canadian companies, without having been fully informed as to the actual facts and conditions.

"Speaking to this resolution, I think it is apparent to all of us from what has appeared lately in the public press, that the Chairman of the Commission has expressed certain opinions on insufficient data. Since the statements reflect on the mining industry of this country, the Institute, in my opinion, should certainly record its protest."

The motion was seconded by Mr. JOHN E. HARDMAN.

The PRESIDENT, before putting the motion said: "There appears to be some little misunderstanding concerning Mr. Brigstocke's resolution. The mover has given me to understand that his object in raising this issue is not by way of an attack on the Hon. Clifford Sifton, the Chairman of the Commission, or, for that matter, on anyone else; but merely that certain erroneous statements which have been publicly uttered and widely reported abroad may be corrected. I shall submit the resolution on that understanding."

The motion was then put to the meeting and carried.*

* At a subsequent Session a motion to rescind the above resolution was proposed by Mr. A. B. Clabon. The resolution however was not seconded.

REPORT OF THE COUNCIL 1909–10.

The Report of the Council for the year ending December 30th, 1909, as follows, was adopted on motion of Prof. J. C. GWILLIM, seconded by Mr. R. W. BRIGSTOCKE.—

The Council, in presenting a report of the work of the Institute for the past year, is gratified to be able to state that the affairs of the Society are now in a more flourishing condition than at any previous time in its history. Not only has there been a steady increase in membership, but greater interest is being evinced by members in the work of the Institute than ever before. The financial position of the Institute is also a sound one; and this is the more satisfactory since the expenses of publication, by reason of the considerable increase of volume of printed matter distributed to members, have now become a very heavy annual charge. In this connection, attention may, perhaps, be called to the fact that Volume XII of the Transactions, for the year 1909, comprises over seven hundred pages; or, in other words, the Institute is at present publishing a volume of twice the size of that of four years ago; and it should be a matter of some pride to members that, in point of value and interest, the Institute's Transactions to-day compare most favourably with those of any mining society in the world. In remarking on this point, thanks and acknowledgments are specially due to those eminent gentlemen (many of whom are members of the United States Geological Survey), who in recent years have attended the Institute's Annual Meetings, and have so generously contributed material of exceptional merit and value to the proceedings.

Referring to other activities of the year, the Institute has reason to congratulate itself on the repeal of sections of the Quebec Mining Law of 1892 and of the substitution therefor of regulations decidedly more conducive to the encouragement of legitimate prospecting and mining in this province. This very welcome change is largely traceable to the Institute's influence and representations.

At the Annual Meeting in March, 1909, a resolution was adopted in which the attention of the Dominion authorities was directed to the urgent present necessity of introducing and placing on the Statutes a Mining Act, wherein proper regulations would

be provided governing the acquisition, development and operation of mining lands under federal control. That such a mining law should be of a nature to encourage rather than retard industry, it was further suggested that before framing an Act, the views of the mining community thereon be ascertained by the appointment of a Royal Commission to secure evidence. No action was taken by the Government in respect of this latter suggestion for the reason that parliament had just previously appointed a Standing Committee on Mines and Mining, whose duties partook largely of those of a Commission; but this Committee immediately entered into communication with the Institute inviting its co-operation and assistance. In consequence four gentlemen, namely, Dr. A. E. Barlow, Mr. J. M. Clark, K.C., Mr. B. A. C. Craig and Mr. J. B. Tyrrell, having special knowledge of the abuses incidental to the present Dominion system of regulating the granting of titles to mineral land, were requested by the council to act as the Institute's representatives, and appear before the Parliamentary Committee as witnesses. They did so, representing to the Committee that since all matters relating to mining on Dominion lands had been heretofore regulated by Orders in Council, stability of conditions were not ensured; and instances were quoted in proof of the contention. The witnesses also advocated the principle of discriminating between surface and mining rights in the granting of titles to public lands, and urged that all business relating to mines and mining be transferred, and be in future conducted by the Department of Mines; pointing out in this connection that although the Department of Mines had now been established for over two years, it was still required that applications for mining areas should be made to the Department of the Interior, which Department also was entrusted with the issuing of grants and patents.

The Parliamentary Committee, since this evidence was presented, have issued a Report recommending (1) that there be assigned to the Mines Department the administration of mines including the issue of title thereto, and of all Mining Laws; (2) that an Act be passed consolidating all the laws relating to mines under federal control; and (3) that consideration be given to a policy which will have for its object the re-acquisition by the Crown of mining rights heretofore granted in patents of land.

In view of this report, the Council trust and believe that the recommendations of the Institute, in respect of the introduction

of favourable Dominion Mining Legislation, will, in the near future, be carried into effect; and advantage is taken of the present opportunity to congratulate the Parliamentary Committee on its efforts in the interests of the mining industry.

MEETINGS.

The eleventh Annual Meeting of the Institute was held at the Windsor Hotel, in the city of Montreal, on March 3rd, 4th and 5th, 1909. The attendance was exceptionally large, there being over two hundred members and others present. The occasion was also notable in that the Institute was honoured by the presence of several eminent gentlemen from the United States, including Mr. S. F. Emmons, and Mr. Waldemar Lindegin of the U. S. Geological Survey; Dr. A. C. Lane, State Geologist of Michigan; Dr. J. F. Kemp, of Columbia University, New York, and Dr. H. Ries, of Ithaca, New York, who presented addresses or papers of great value, and otherwise materially contributed to the success and interest of the meeting. The Institute was also privileged to entertain at its annual dinner, His Excellency, the Governor-General, who delivered a most interesting address; the Hon. Wm. Templeman, Minister of Mines for the Dominion, the Hon. Frank Cochrane, Minister of Mines of Ontario, and other eminent Canadian Parliamentarians.

Other meetings held during the year have included those at Rossland, Nelson and Spokane, under the auspices of the Western Branch; and Branch Meetings at Cobalt and Montreal.

Five Regular Meetings of Council have been held at Headquarters, whilst a special meeting was held in Toronto in the month of July.

PUBLICATIONS.

The papers presented at Annual Meeting, together with those read at the Branch Meetings, and also others transmitted direct to the Secretary, in all forty-two papers contributed by members, associates and student members, together with the discussions thereon, have been published in Volume XII of the Journal of the Institute, copies of which have been distributed to members in good standing.

There have also been published and distributed during the year four bulletins, in which have been printed papers "subject to revision," notices and other matter of interest to the general membership.

BRANCHES.

Both the Cobalt and Western Branches have been very active during the year, and show substantial membership gains. In addition to holding two well attended regular meetings in British Columbia, the Western Branch accepted an invitation to participate in a joint meeting in Spokane with the American Institute of Mining Engineers in September last; whilst under the leadership of the President of the Institute, the Cobalt branch acted as host to a party representing the geological section of the British Association, who had been invited to visit the mines of this district. The party accompanied by representatives of the Institute, subsequently visited Temagami, Sudbury, Moose Mountain, Copper Cliff and Silver Islet; and after attending the general meeting of the Association in Winnipeg, continued the journey across the continent to Vancouver.

LIBRARY AND READING ROOM.

The present location of the Institute's office in the Windsor Hotel, Montreal has proved a very great convenience to members visiting headquarters, who have availed themselves freely of the facilities afforded them to consult the library, or make use of the reading room. Many visitors from Great Britain and abroad desirous of obtaining information anent Canadian mines and mining, have also called at the offices to seek the Secretary's assistance or advice; and, it is believed, that the possibilities of rendering valuable and useful service in this direction are very considerable, more especially when the fact that the Institute is prepared to supply information to those requiring it becomes more generally known. In order to advertise its readiness in this respect in Great Britain, the High Commissioner's office in London has been notified that the Institute is prepared to receive and reply to any enquiries on the subject of Canadian mining.

Little or no expenditures have been made this year on library account; but numerous donations of books have been received, particulars of which have been published in the Institute's Bulletins.

SECRETARY'S OFFICE.

The following returns are taken from the Secretary's records for the eleven months ending December 31st, 1909:—

Letters received	2,274
Letters written, notices, etc.	6,395
Circulars issued	7,400
Publications issued	6,200.

STUDENTS' COMPETITION AND AWARDS.

In 1909, ten papers were submitted by student members in competition for the Institute's annual awards. After receiving the report of the judges, namely, Dr. H. Ries of Cornell University, Ithaca, N.Y., Mr. Arthur A. Cole, of Cobalt, Ont., and the Secretary, who acted in an *ex-officio* capacity, the Council has awarded the President's Gold Medal to Mr. N. L. Bowen, of the School of Mining, Kingston. In addition Mr. Bowen received a cash prize of twenty-five dollars; while cash prizes of twenty-five and twenty dollars, respectively, were awarded to Mr. E. P. Cowles, of McGill University, and Mr. G. J. Burland, of McGill University. The papers submitted by Messrs. King, Rider, Rutherford and White received honourable mention. The following excerpt from the Judge's Report may be of interest to members:—

"The undersigned, having been requested to adjudicate on the papers submitted by the Student members of the Institute in competition for the awards offered by the Council for the year 1909, beg to report as follows:—

"The number of papers entered for the 1909 competition was ten. Of this number, eight—a relatively large proportion—are regarded as being sufficiently meritorious to justify the recommendation that they be published in the Institute's Transactions.

"In short, the papers submitted this year appear, in point of merit and presentation, to be rather above the average of like contributions to the Institute by students in recent years.

"After careful consideration, we recommend that the first prize and the President's Gold Medal, be awarded to Mr. N. L. Bowen of the School of Mining, Kingston, for his paper entitled 'Diabase and Aplite of the Cobalt Silver Area.' In this paper, matter and manner are equally satisfactory. The subject is not only well

presented, but it is also plain that the problem discussed has been carefully and conscientiously studied, by the tabulation and comparison of conclusions arrived at by recognized authorities with the records of the author's own observations in the field. The paper is quite the most distinguished in point of originality of any entered for this competition, and is worthy of high praise.

"The second place is awarded to Mr. E. P. Cowles of McGill University, for his paper entitled 'The Caledonia Mine, Cape Breton.' This paper has the merit of being a sincere and straightforward endeavour, winning its position largely for the reason that its author depended entirely on his own data, compiled from observations while working as a miner at the colliery in question, for material on which to base the thesis.

"The third prize is awarded to Mr. G. L. Burland, of McGill University, for his paper entitled 'The Mines and Ovens of the International Coal & Coke Company.' This paper is highly commendable, the author having evidently gone to immense pains in assembling and compiling facts and information. The drawings accompanying this paper are also exceptionally well executed.

"Four papers, namely, those by Messrs. King and White, of the School of Mining, Kingston, and by Messrs. Rider and Rutherford, of McGill University, Montreal, respectively, although falling short of the standard set by the prize-winners, are nevertheless, deserving of Honourable Mention. Of the four, Mr. King displays the greater degree of originality, but fails to make as much of his subject as he might have done. Mr. Rutherford's paper on 'Coal Mining in the Pictou District, C.B.' is reasonably well written and evidences a good sense of proportion. He has, however, depended too largely on authorities to deserve higher recognition. The same comment is also applicable to Mr. White's paper entitled 'Chrome Bearing Peridotites of the Abitibi District.' Mr. Rider's paper on 'The King's Asbestos Mines, Thetford Mines, Que.' is an interesting summary of operations in this area."

FRECHEVILLE—COMMANS—MARIOTT COMPETITION.

Three of the gentlemen, namely, Messrs. R. E. Commans, Wm. Frecheville and Hugh F. Mariott, who participated in the Institute's Summer Excursion of 1908, as representatives of the Institution of Mining and Metallurgy, desiring to give definite

expression of their appreciation of the hospitality they received on that occasion, early last year communicated with the Council requesting permission to donate the sum of fifty guineas as a prize to be offered for the best paper contributed by a junior member (namely one under thirty years of age) to the Institute's Transactions before January 1st, 1910, on a subject descriptive of any mining or metallurgical improvements effected in Canada during the year from October 1st, 1908. The offer having been gratefully accepted, the Council appointed three of its members, namely, Messrs. J. Bonsall Porter, J. C. Gwillim, and H. E. T. Haultain, a committee to direct the competition; and under instruction from the committee, a circular affording particulars of and conditions governing the competition, was duly issued to members in April last. In response to this circular, five papers have been forwarded to the Secretary for submission to the committee.

MEMBERSHIP.

The membership of the Institute, inclusive of all classes, now totals nine hundred and thirty-five (935). The accessions during 1909 were as follows:—

Corresponding Members	2
Ex-officio members	1
Members	70
Associates	20
Students	4

It may be here noted that the mining students of the "École Polytechnique," Montreal, have recently organized a Mining Society, and have applied for affiliation with the Institute. The present membership of this Society is twenty-five.

With a view to establishing and promoting friendly relationship between the Institute and the Institution of Mining and Metallurgy, the Council in July last submitted a proposal to the Council of the latter organization, offering to provide in future that members of the Institution of Mining and Metallurgy, non-resident in Canada should be admitted to membership of the Institute upon payment of a reduced annual subscription of five dollars. This offer having been accepted, a By-Law in accordance

therewith has been prepared for submission to and for the consideration of the Annual Meeting.

DEATHS.

The Council records with profound regret the deaths during the year of the following members:—

Members—Mr. E. L. Fraleck, Member of Council; Mr. Andrew Colville, Mr. Hugh Fletcher, Mr. A. L. Fowler.

Associates—Mr. John Ferguson, and Mr. Harvey D. Graham.

RESIGNATIONS.

The following gentlemen have resigned their membership:—

Members—R. Auzias-Turenna, Dwight Brainard, Geo. E. Corbett, Dr. C. W. Dickson, A. A. Hayward, Wm. Earl Hidden, J. T. Hillis, W. A. Hungerford, Norman L. Leach, John S. MacLean.

Associates—K. C. Allen, R. G. Gaskin, F. Asa. Hall, J. T. Horne, Ed. W. Monk, Arthur P. Naismith.

(Signed) H. MORTIMER-LAMB, Secretary.

FINANCIAL STATEMENT.

RECEIPTS AND DISBURSEMENTS.

FOR ELEVEN MONTHS ENDING DECEMBER 31ST, 1909.

Receipts.

Annual subscriptions	$5,331.00	
" " Students'	180.00	
" " Arrears Paid	337.15	
		$5,848.15
Advertisements		379.00
Sale of publications		155.27
Bank interest		114.82
Government grants		4,000.00
		$10,497.24

Disbursements.

Publications	$2,948.21	
Rent and taxes	687.50	
Salaries	1,213.66	
Printing and stationery	505.17	
Express	52.46	
Postage	258.68	
Telegrams and telephones	72.00	
Travelling expenses	190.40	
General	199.73	
Advertising	25.00	
Western Branch	498.10	
Cobalt	100.00	
Annual Meeting	593.88	7,344.79
		$3,152.45
Less to complete volume (say)		1,700.00
		$1,452.45

SUMMARY STATEMENT.

SHOWING DISTRIBUTION AND DISBURSEMENTS TO THE VARIOUS WORK AND BUSINESS OF THE INSTITUTE.

Publications.

Transactions, Volume XII.		$2,948.21	
Postage and Express.		210.46	
Sundries.		8.92	
			$3,167.59

Library.

Rent		$ 687.50	
Insurance.		43.05	
Telephone		40.00	
			$ 770.55

Meetings.

Annual Meeting		$ 593.88	
Printing and stationery		130.83	
Council (travelling expenses, printing, etc.),		73.70	
			$ 798.41

Secretary and Treasurer's Office.

Salaries.	$2,813.66		
Less chargeable to publications.	1,600.00		
		$1,213.66	
Printing and stationery.		316.51	
Postage, telegrams, etc.		132.68	
Travelling expenses.		139.40	
Bank exchanges		39.82	
Audit, etc.		55.00	
Advertising.		50.00	
Sundries.		27.94	
			$1,975.01

Branches.

Western Branch.		$ 498.10	
Western printing and stationery		35.13	
Cobalt (branch meeting)		100.00	
			$ 633.23
TOTAL			$ 7,344.79

THE MINERAL PRODUCTION OF CANADA IN 1910.

Mr. J. McLeish, statistician of the Department of Mines, Ottawa, then presented, upon the invitation of the President, the following statistical returns of mineral production of Canada for the calendar year, 1909:

"The total value of the mineral production in Canada during the calendar year 1909, as shown in the preliminary report just issued by the Mines Branch of the Department of Mines at Ottawa, exceeded the sum of $90,000,000 and is the largest production that has been recorded in Canadian mining history.

"The production per capita in 1909, which was about $12.62, was somewhat less than the per capita production of 1907 when the output per head averaged $13.35.

"By provinces the production may be subdivided as follows:—

Nova Scotia	$ 12,598,004
New Brunswick	623,333
Quebec	6,526,185
Ontario	36,729,089
Manitoba	790,495
Saskatchewan	410,069
Alberta	5,953,928
British Columbia	22,798,909
Yukon	3,985,751
	90,415,763

"These figures may differ somewhat from totals published by the Provincial Mining Bureaus, owing to different methods on the inclusion or otherwise of the value of products made from imported ores.

"Details of the total mineral production in 1909 are shown in the following table:—

PRELIMINARY REPORT ON THE MINERAL PRODUCTION OF CANADA IN 1909.

Product.		Quantity. (a)	Value. (b)
METALLIC.			$
Copper (c)	Lbs.	54,061,106	7,018,213
Gold			9,790,000
Pig iron from Canadian ore (d)	Tons.	149,444	2,222,215
Iron ore (exports)	"	21,956	61,965
Lead (e)	Lbs.	45,857,424	1,959,488
Nickel (f)	"	26,282,991	9,461,877
Cobalt			* 66,319
Silver (g)	Ozs.	27,878,590	14,358,310
Zinc			250,000
Total value, metallic			45,188,387
NON-METALLIC.			
Arsenic	Tons.	1,129	64,100
Asbestos	"	63,349	2,284,587
Asbestic and asbestic sand	"	23,951	17,188
Chromite (exports)	"	1,794	20,858
Coal	"	10,411,955	24,431,351
Corundum	"	1,491	157,398
Feldspar	"	10,286	35,694
Graphite	"	730	37,624
Grindstones	"	3,965	50,944
Gypsum	"	468,551	667,816
Magnesite	"	330	2,508
Mica	"		154,106

(a) Quantity of product sold or shipped.

(b) The metals, copper, lead nickel and silver are for statistical and comparative purposes valued at the final average value of the refined metal in New York. Pig iron is valued at the furnace and non-metallic products at the mine or point of shipment.

(c) Copper contents of smelter products and ores exported at 12.982 cents per pound.

(d) The total production of pig iron in Canada in 1909 was 757,162 tons valued at $9,581,864, of which it is estimated 607,718 tons valued at $7,359,649 should be credited to imported ores.

(e) Refined lead and lead contained in base bullion exported at 4·273 cents per pound.

(f) Nickel contents of matte produced, at 36 cents per pound (the lowest quotation for nickel in New York less 10 per cent). The value of the nickel contained in matte was, as returned by the operators, $2,810,748 or an average per pound of 10.7 cents.

* Additional returns increase this item to $90,950.

(g) Estimated recoverable silver at 51.503 cents per ounce.

Product.		Quantity.	Value.
Mineral pigments—.			
Ochres and Barytes	Tons	4,119	29,213
Mineral waters			177,304
Natural gas (*h*)			1,205,943
Petroleum (*i*)	Brls.	420,755	559,604
Phosphate (apatite)	Tons.	597	4,618
Pyrites	"	57,038	196,312
Quartz	"	50,541	63,032
Salt	"	84,037	415,219
Talc	"	4,506	12,172
STRUCTURAL MATERIAL AND CLAY PRODUCTS.			
Cement, Portland	Brls.	4,010,180	5,266,008
Clay products—			
Brick			4,200,000
Sewer pipe, fireclay, drain tile, etc			1,300,000
Lime	Bush.	5,163,874	1,049,473
Sand and gravel (exports)	Tons.	481,584	256,166
Stone—			
Granite			340,047
Limestone for flux in blast furnace			328,091
Marble, limestone and sandstone			1,600,000
Total structural material and clay products			14,339,785
All other non-metallic			30,587,591
Total value, non-metallic			44,927,376
Total value, metallic			45,188,387
Estimated value of mineral products not reported			300,000
Total value, 1909			90,415,763

(*h*) Gross returns for sale of gas.

(*i*) Quantity on which bounty was paid and valued at $1.33 per barrel.

"The high value of the mineral output in 1909 has not been due to any spasmodic outburst of mining activity; but is rather the result, speaking generally, of keen business management and able scientific direction of substantial industries. There have been no new Klondikes or second Cobalts contributing large outputs to inflate the value of the production. On the contrary, in the case of not a few mineral products former years have shown higher outputs. The gold production in 1900 was nearly three times what it was in 1909. The productions of lead, coal, asbestos and petroleum have all been greater in some previous year, though on

the other hand nickel, silver, pig iron, and many of the non-metallic products including gypsum, natural gas, salt, cement, clay products, lime and stone show maximum outputs during the past year. The year has been marked by a number of important consolidations of interests resulting in the formation of such organizations as the Amalgamated Asbestos Corporation, the Canada Cement Co., Ltd., the Steel-Coal Merger, etc., and there is probably little doubt but that these consolidations will be of immense benefit to the mining industry from an administrative and technical point of view.

"It is very satisfactory also to observe the growth of our metallurgical industries, although there is still vast room for development in the home treatment not only of our metals but also of our non-metallic products. A large iron and steel industry has grown up in Eastern Canada with an annual output of over 750,000 tons of pig iron and about an equal amount of steel ingots and castings; steel rails and other rolling mill products are being manufactured, and two of the largest iron and steel firms are about to erect large plants for the manufacture of structural steel. Our lead is now nearly all produced as refined pig lead; over 25 per cent of our copper is produced as blister and the greater part of the balance as matte. Over 55 per cent of the silver production is fine metal and fine silver bullion. Nickel is nearly all produced in Bessemer matte. At the Trail smelter in British Columbia, in addition to refined lead and silver, there is produced refined gold, refined antimony, babbit metal and copper sulphate. In Ontario white arsenic in addition to refined silver is being recovered at those plants treating Cobalt district ores, and at Thorold cobalt oxide is being made in small quantities.

"The aggregate results of smelter production during 1908 and 1909 are shown in the following table. It should be explained that the figures include the results of the treatment of a small quantity of imported ores, and that the results of operation at the smelter at Northport, Wash., treating chiefly Canadian ores, have also been included.

SMELTER AND REFINERY PRODUCTION IN CANADA, 1908 AND 1909

		1908.		1909.	
		Refined Products.	Metals contained in matte, blister, base bullion, and speiss exported.	Refined Products.	Metals contained in matte, blister, base bullion, and speiss exported.
Gold	Ozs.	15,436	203,300	18,241	200,129
Silver	"	11,168,689	3,271,899	14,242,545	4,845,920
Lead	Lbs.	36,549,274	1,116,792	41,883,614	3,973,810
Copper	"	.....	51,965,289	.....	53,328,583
Copper sulphate	"	203,379	.....	51,405	.....
Nickel	"	.....	19,506,251	.....	27,041,857
Cobalt	"	.....	692,170	.....	1,721,083
White arsenic	"	1,431,052	.....	2,258,087	.....
Arsenic	"	.....	436,787	.....	1,074,516

"The total ore charged to the furnaces in 1909 was 2,377,780 tons, of which slightly over 40,000 tons were imported. The smelter products exported for refining included, in 1908, copper matte 7,649 tons; blister copper 15,418 tons; Bessemer nickel-copper matte 21,210 tons and silver-cobalt-nickel speiss 1,326 tons. In 1909 these smelter products were base bullion 2,010 tons; copper matte 11,597 tons; blister copper 14,329 tons; Bessemer nickel-copper matte 25,845 tons; silver-cobalt-nickel speiss 2,660 tons.

"Of the total production in 1909, $45,188,387—or 49.9 per cent of the total—is credited to the metals, and 44,927,376—or 49.7 per cent—to non-metallic products; a small allowance being made for mineral products not reported. Amongst the individual products coal is still the most important, its value constituting 27 per cent of the total; silver occupies second place with 15.9 per cent; gold and nickel come next with 10.8 and 10.5 per cent respectively; copper contributes 7.8 per cent; cement 5.8 per cent; clay products 6.1 per cent; asbestos 2.5 per cent.

"The metals nearly all showed an increased output compared with 1908. The average prices remained fairly steady throughout the year, differing but slightly from those of the year before: copper, nickel and silver, being lower in price, while lead, spelter and tin, were higher.

"A comparison of New York average monthly prices is shown herewith.

AVERAGE MONTHLY PRICES OF METALS, 1906-09.

	1906.	1907.	1908.	1909.
	Cts.	Cts.	Cts.	Cts.
Copper	19.278	20.004	13.208	12.982
Lead	5.657	5.325	4.200	4.273
Nickel	41. 64	45.000	43.000	40.000
Silver	66.791	65.327	52.864	51.503
Spelter	6.198	5.962	4.720	5.503
Tin	39.819	38.166	29.465	29.725

"In the non-metallic class there is a larger number of products showing increases than those showing decreases. The coal production was seriously reduced by the labour troubles in Nova Scotia. The asbestos shipments were somewhat less and petroleum production shows a considerable falling off. In nearly all of the other items, however, there were important increases: particularly in corundum, gypsum, natural gas, salt, and in the structural materials, cement, clay products, lime and stone.

Gold.—A preliminary estimate shows a slight decrease in gold production in 1909. The total production in 1908 was $9,842,105, to which the Yukon district contributed $3,600,000; British Columbia $5,929,880; Nova Scotia $244,799. In 1909 the Yukon shows a further increase, the value of the gold being estimated at $3,960,000. The total gold exports on which royalty was paid, were, according to the records of the Interior Department, during the calendar year, 239,766.35 ounces.

Complete statistics are not yet available as to the gold production in British Columbia, but the returns received appear to indicate a reduced output. The production in Nova Scotia will not differ much from that of the previous year.

Silver.—The total production of recoverable silver in Canada is estimated at 27,878,590 ounces valued at $14,358,310, the average price of silver for the year being 51.503 cents.

The price of refined silver varied between a maximum of $53\frac{7}{8}$ cents per ounce on May 5th, and a minimum of $50\frac{1}{4}$ on March 3rd.

The production from the Cobalt district again shows a considerable increase over the previous year, but not so large an advance as was made in 1908 over 1907. According to returns received from 31 shipping mines, there were shipped during 1909 about 28,042 tons of ore and 2,967 tons of concentrates, a total tonnage of 31,009. The silver contents of ore shipped are returned as 22,581,788 ounces or an average of 805.284 ounces per ton, and for the concentrates shipped 3,639,475 ounces or an average of 1,226.651 ounces per ton. Bullion shipped from the mines contained 143,440 fine ounces of silver.

The total silver contents of ore, concentrates and bullion shipped from the mines was 26,364,703 ounces. The mine owners receive payment for only 93 to 98 per cent of the silver contents; and in valuing the production a deduction of 5 per cent is made from silver contained in ore and concentrates to cover losses in smelting and refining. On this basis the silver recovery is estimated at 25,128,590 ounces, and valued at $12,941,978. Payments for cobalt contents were reported as $90,750, the total value of the year's output was a little over $13,000,000 without deductions for freight and treatment charges.

The number of men employed in shipping mines was reported as 2,768, and wages paid $2,396,742. Incomplete returns of concentration showed 127,271 tons of ore treated, producing 3,213 tons of concentrates.

In 1908 the shipments were 25,682 tons of ore and concentrates containing 19,398,545 ounces of silver, or an average of 755 ounces per ton.

Copper.—Statistics are not available at the present time to show the total quantity of copper contained in ores shipped from the mines. The total production of copper, however, contained in blister and matte produced and estimated as recoverable from ores exported, was in 1909 approximately 54,061,106 pounds. In 1908 the production of copper estimated on the same basis was 52,928,386 pounds, an increased production of about 2 per cent being, therefore, shown in 1909.

Of the production in 1909, Ontario is credited with 15,746,699 pounds and British Columbia with 37,314,407 pounds. The latter figure may be subject to more or less variation as complete returns had not been received of all ore exported.

The New York price of electrolytic copper varied between the limits of 12 cents and 14⅝ cents per pound, the average monthly price being 12.982 as compared with an average monthly price of 13.208 cents in 1908.

The total exports of copper contained in ore matte and blister, according to Customs Department returns, were 54,447,750 pounds, valued at $5,832,246.

"*Lead.*—The total production in 1909 of pig and manufactured lead and lead contained in base bullion exported was 45,857,424 pounds valued at the average price of refined lead in New York at $1,959,488.

"It is possible that there was also some lead ore or lead concentrates exported, of which no record has yet been received. Custom Department statistics indicate such an export of upwards of 2,000,000 pounds.

"The production of refined lead and lead contained in base bullion exported in 1908 was 37,666,066.

"Customs Department statistics in this year also indicate an export of lead ore or concentrates, and the total production in 1908, of lead available for consumption was estimated at 40,891,448 pounds, an increased production in 1909 is, therefore, shown of from 5,000,000 to 7,000,000 pounds. This production in both years was all from the province of British Columbia.

"The total amount of bounty paid during the twelve months ending December 31, 1909, on account of lead production was $346,527.98.

"The exports of lead in ore, concentrates, base bullion, etc., during the year were 3,116 tons and of pig lead 5,650 tons or a total of 8,766 tons. From 14,000 tons to 15,000 tons of domestic production were, therefore, available for home consumption.

"The price of lead in New York during 1909 averaged 4.273 cents per pound, varying between 3.95 cents in March and 4.70 cents in December. In 1908 the average was 4.200 cents per pound. The London price per long ton varied between £12 10s. and £13 16s., averaging £13.049.

"*Nickel.*—The nickel industry was particularly active during 1909, the largest production on record being shown. Although important quantities of nickel are contained in the cobalt-silver ores of Coleman township, the Sudbury district continues to be the

chief source of nickel production. The same companies are carrying on active operations: the Mond Nickel Co., at Victoria Mines and the Canadian Copper Co. at Copper Cliff. The ore is first roasted and then smelted to a Bessemer matte containing from 77 to 82 per cent of the combined metals, copper and nickel; the matte being shipped to the United States and Great Britain for refining.

"The total production of matte in 1909 was 25,845 tons, valued at the furnaces at $3,913,012. The metallic contents were copper 15,746,699 pounds, nickel 26,282,991 pounds.

"The aggregate results of the operations on the Sudbury district nickel-copper ores during the past four years are as follows:—

	1906. Tons of 2,000 lbs	1907. Tons of 2,000 lbs.	1908. Tons of 2,000 lbs.	1909. Tons of 2,000 lbs.
Ore mined	343,814	351,916	409,551	451,892
Ore smelted	340,059	359,076	360,180	462,336
Bessemer matte produced	20,364	22,041	21,197	25,845
" shipped	20,310	22,025	21,210	.....
Copper contents of matte shipped	5,265	6,996	7,503	7,873
Nickel contents of matte shipped	10,745	10,595	9,572	13,141
Spot value of matte shipped.	$ 4,628,011	$3,289,382	$2,930,989	$3,913,012
Wages paid	1,117,420	1,278,694	1,286,265	1,234,903
Men employed	1,417	1,660	1,690	1,735

"Nickel contained in silver cobalt ores:—The mine owners received no payment for nickel contents and complete statistics are not available as to the total quantity of nickel contained in these ores, of which about 31,009 tons were shipped during 1909. Of the total shipments 8,384 tons were treated in Canadian metallurgical works at Copper Cliff, Deloro and Thorold, producing silver bullion and white arsenic, the remaining speiss or residues amounted to 2,660 tons and contained silver, cobalt, nickel and arsenic, the nickel contents totalling 758,966 pounds and the cobalt contents 1,721,083 pounds.

"The price of refined nickel in New York was quoted at from 40 to 50 cents per pound, the quotations in December being "large lots, contract business 40 to 45 cents per pound; Retail spot from

50 cents for 2,000 pound lots up to 55 cents for 500 pound lots. The price for electrolytic is 5 cents higher.

"*Iron ore.*—The total shipments of iron ore from mines in Canada in 1909 were 268,043 short tons, valued at $659,120, as compared with 238,082 tons valued at $568,189 in 1908. The shipments in 1909 may be classified as magnetites 73,420 tons; hematite 190,473 tons; bog ore 3,330 tons; titaniferous magnetite (sand) for experimental purposes 820 tons. In 1908 the ores shipped included magnetite 49,946 tons; hematite 173,164 tons; carbonate ore 4,869 tons; bog ore 10,103 tons.

"Exports of ore from Canada during 1909, as recorded by the Customs Department, were 21,956 tons valued at $61,965.

"Although not a portion of the Dominion of Canada, it may be of interest to state the iron ore shipments from Newfoundland during 1909. The two Canadian companies operating the Wabana mines shipped during the year 991,115 gross tons or 1,110,049 short tons, of which 697,068 tons were shipped to Sydney and 412,981 tons to the United States and Europe.

"*Pig Iron.*—An increase of 20 per cent is shown in the production of pig iron in Canada in 1909 as compared with 1908, despite the fact that the Londonderry furnace was out of commission during the whole year. The total production during 1909 was 757,162 short tons valued at $9,581,864 as compared with 630,835 tons valued at $8,111,194 in 1908. These figures do not include the output from electric furnace plants, making ferro products, which are situated at Welland and Sault Ste. Marie, Ontario, and Buckingham, Que.

"Of the total output of pig iron during 1909, 17,003 tons valued at $371,368 or $21.84 per ton were made with charcoal as fuel and 740,159 tons valued at $9,210,496 or $12.44 per ton with coke. The amount of charcoal iron made in 1908 was 6,790 tons, and iron made with coke 624,126 tons. The classification of the production in 1909 according to the purpose for which it was intended was as follows: Bessemer 222,931 tons; basic 400,921 tons; foundry, including miscellaneous, 116,307 tons.

"The amount of Canadian ore used during 1909 was 231,994 tons, imported ore 1,234,990 tons, mill cinder, etc., 25,508 tons. The amount of coke used during the year was 919,271 tons, comprising 412,016 tons from Canadian coal and 507,255 tons im-

ported coke or coke made from imported coal. The consumption of charcoal was 1,782,258 bushels. Limestone flux was used to the extent of 526,076 tons. In connection with blast furnace operations there were employed 1,486 men and $879,426 were paid in wages.

"The total daily capacity of 16 completed furnaces was, according to returns received, 2,735 tons. The number of furnaces in blast on December 31, 1909, was 11.

"The production of pig iron by provinces in 1908 and 1909 was as follows:—

Province.	1908.			1909.		
	Tons.	Value.	Per ton	Tons.	Value.	Per ton.
		$	$ cts.		$	$ cts.
Nova Scotia. .	352,642	3,554,540	10 08	345,380	3,453,800	10 00
Quebec.	6,709	171,383	25 55	4,770	125,623	26 34
Ontario.	271,484	4,385,271	16 15	407,012	6,002,441	14 75
Total. . . .	630,835	8,111,194	12 86	757,162	9,581,864	12 65

"*Steel.*—Returns were received from eight steel plants at which 2,073 men were employed and $1,284,940 paid in wages during 1909. The total production of ingots and castings was 754,719 short tons with an estimated value of $14,359,710 as compared with 588,763 tons valued at $10,916,602 in 1908.

"Details of production during the two years are as follows:—

	1908.		1909.	
	Tons.	$	Tons.	$
Ingots—Open hearth (basic). .	443,442	7,684,277	535,988	9,372,615
Bessemer (acid).	135,557	2,535,287	203,715	3,829,012
Castings—Open hearth.	9,051	617,126	14,013	1,043,370
Other steels.	713	79,912	1,003	114,713
Total.	588,763	10,916,602	754,719	14,359,710

"*Iron and Steel Bounties.*—Following is a statement of the bounties paid on iron and steel during the calendar years 1908 and 1909, as kindly furnished by the Trade and Commerce Department. As no bounty is paid on iron made from mill cinder or ingredients other than ore, the figures do not show the total output of the furnaces but only those quantities on which bounty was paid.

	1908.		1906.	
	Quantity on which Bounty was paid.	Bounty.	Quantity on which Bounty was paid.	Bounty.
	Tons.	$ cts.	Tons.	$ cts.
Pig iron made from Canadian ore.....	101,647	213,458 34	126,297.55	214,705 80
Pig iron made from imported ore.....	517,427	569,166 93	607,718.09	425,402 64
Total, pig iron...	619,074	782,628 27	734,015.64	640,108 44
Steel ingots.....	556,289	917,876 63	729,189.37	766,470 41
Steel wire rods.....	49,630	297,778 68	81,405.42	488,432 70
Total bounty paid on iron and steel		1,998,283 58	.....	1,895,011 55

"*White arsenic.*—The total output of white arsenic as reported by three firms making this product was 2,258,187 pounds, valued at $64,100. In addition the residues or speiss from these works exported contained 1,074,511 pounds of arsenic. This is all obtained from that portion of the Cobalt ores treated in Canada. No record is available of the total arsenical contents of these ores. The exports of arsenic are reported as 3,111,249 pounds valued at $119,673. The production of white arsenic in 1908 was 1,431,000 pounds valued at $41,060 and of arsenical ore and concentrates 986 tons valued at $17,506.

"*Asbestos.*—A feature of special interest in connection with the asbestos industry during 1909 has been the consolidation of interests amongst a number of the larger producers, resulting in the formation of the Amalgamated Asbestos Corporation Ltd.

"While the actual shipments of asbestos were somewhat less in 1909 than in 1908 the stocks on hand at the end of the year are reported considerably larger than on December 31, 1908.

"The total shipments of crude and mill stock in 1909 were 63,349 tons valued at $2,284,587 as compared with shipments of 66,548 tons valued at $2,555,361 in 1908, the decrease being 3,199 tons or 4.8 per cent. The stocks on hand December 31, 1909, were about 20,920 tons, valued approximately at $1,179,679 as compared with stocks on hand December 31, 1908, of 8,669 tons valued at $596,095.

"The total shipments, showing details of crude and mill stock were in 1908 and 1909, as follows:—

	1908.			1909.		
	Short Tons.	Value.	Per ton.	Short Tons.	Value.	Per ton.
		$	$ cts.		$	$ cts.
Crude, No. 1. .	857½	257,752	300 59	912.3	246,655	270 37
" 2. .	2,488	411,480	165 38	2,162	328,855	152 11
Mill Stock No. 1.	5,282½	425,448	80 54	14,776	785,731	53 18
Mll Stock No. 2.	45,545¼	1,345,750	29 33	32,417	800,728	24 70
Mill Stock No. 3.	12,374¼	114,931	9 29	13,082	122,618	9 37
Total asbestos	66,548	2,555,361	38 40	63,349.3	2,284,857	36 06
Total asbestic.	24,225	17,974	0 74	23,951	17,188	0 72
Grand total. . .	90,773	2,573,335	. . . . .	87,300.3	2,301,775	. . . . .

"*Corundum.*—The quantity of corundum ore treated during the year was 35,894 tons, from which was produced 1,579 tons of grain corundum. The total shipments were 1,491 tons valued at $157,398, or an average of a little over 5 cents per pound.

"*Coal and coke.*—The total coal production in Canada in 1909, comprising sales and shipments, colliery consumption and coal used in making coke, is estimated at 10,411,955 short tons, valued at $24,431,351. This is a smaller production than in either of the two preceding years, though the total may be slightly increased when more complete returns are received. The western provinces each show an increased production of coal in 1909; but not sufficient to counteract the reduced output in Nova Scotia,

which resulted from the coal miners' strike. The aggregate decrease for the whole of Canada was about 474,356 tons or 4.36 per cent; while Nova Scotia alone showed a falling off of 968,789 short tons or 14.56 per cent, the aggregate increase in the western provinces being 505,404 tons or 12.11 per cent.

"Of the total production Nova Scotia contributed 54.5 per cent, Saskatchewan and Alberta 20.5 per cent and British Columbia 24.3 per cent.

"The production by provinces, was approximately as follows, the figures for 1907 and 1908 being also given:—

Province.	1907.		1908.		1909.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
		$		$		$
Nova Scotia	6,354,133	12,764,999	6,652,539	13,364,476	5,683,750	11,418,249
British Columbia.	2,364,898	7,390,306	2,333,708	7,292,838	2,538,004	7,931,263
Alberta	1,591,579	3,836,286	1,685,661	4,127,311	1,978,843	4,730,270
Saskatchewan ...	151,232	252,437	150,556	253,790	163,329	253,073
New Brunswick..	34,584	77,814	60,000	135,000	49,029	98,496
Yukon Territory .	15,000	60,000	3,847	21,158	.....	.....
Totals	10,511,426	24,381,842	10,886,311	25,194,573	10,411,955	24,431,351

"The total production of oven coke in 1909 was about 875,080 short tons valued at $3,557,147, being a slight increase over the production in 1908. At the ovens of the Dominion Iron and Steel Co., at Sydney a quantity of imported coal was used, the supply of domestic coal being insufficient on account of the strike. The Atikokan Iron Company at Port Arthur uses imported coal exclusively. At all other ovens Canadian coal is used. At the end of the the year there were in Nova Scotia 670 ovens in operation, 64 idle and 120 building. In Alberta 226 were in operation and 40 idle and in British Columbia 767 in operation and 753 idle. The ovens of the Dominion Iron and Steel Co. are of the Otto Hoffman by-product type and there were recovered as by-products 4,016,824 gallons of tar and 3,351 short tons of sulphate of ammonia.

"*Feldspar.*—Total shipments are reported as 10,286 tons. valued at $35,694. This includes a quantity of high grade "dental spar" shipped from the Villeneuve mine, Quebec, and valued at from $16 to $20 per ton at Buckingham.

"*Petroleum and Natural Gas.*—The production of crude petroleum was as usual nearly all derived from the Ontario peninsula. Direct returns from the producers have not been obtained, but the production upon which bounty was paid, ascertained by the Trade and Commerce Department was 14,726,433 gallons, of which 3,328 gallons were produced in New Brunswick. This is equivalent to 420,755 barrels and at an average price of $1.33 per barrel was valued at $559,604. The production in 1908 was 527,987 barrels valued at $747,102, an average per barrel of $1.34, showing a decrease of about 20 per cent in the quantity produced. The total bounty paid in 1909 was $220,896.50 as compared with $277,193.21 in 1908 and $414,157.89 in 1907.

"While the production of petroleum has been falling off the receipts from natural gas sold have been increasing. The producing gas wells are located in the counties of Welland, Haldimand, Norfolk, Kent, Essex, and Bruce in Ontario, and at Medicine Hat and vicinity in Alberta. The total receipts from gas sold in 1909 were about $1,205,943, the figures representing, with one or two exceptions, the total values paid by the consumers.

"The quantity of gas sold or used during the year was over 6,000,000 M. feet. Of the total value about 95 per cent is to be credited to Ontario. The total receipts in 1908 were $1,012,660.

"*Phosphate.*—The price of this mineral has been increasing. There is a growing demand for it and a revival of phosphate mining appears to be imminent.

"*Salt.*—Complete returns of salt production received show total sales of 84,037 tons, valued at $415,219 for the salt alone. Packages used were valued at $175,612; stock on hand at the end of the year was reported as 2,671 tons; 185 men were employed, and $96,116 paid in wages.

"*Lime.*—Fairly complete statistics of lime production have been received for 1909. The total sales and shipments are reported as 5,163,874 bushels valued at $1,049,473, or by provinces as follows: Nova Scotia and New Brunswick 747,696 bushels, valued at $179,380; Quebec 1,155,167 bushels, valued at $277,253; Ontario 2,434,686 bushels, valued at $404,782; Western Provinces 826,325 bushels, valued at $188,058.

"*Portland Cement.*—Complete statistics have been received from all but two cement manufacturers in 1909. These, however, will not increase the totals by more than 2 or 3 per cent. Subject to this correction the total quantity of cement made during the year was 4,089,191 barrels as compared with 3,495,961 barrels in 1908, an increase of 593,230 barrels or 17 per cent.

"The total quantity of Canadian Portland cement sold during the year was 4,010,180 barrels, as compared with 2,665,289 barrels in 1908, an increase of 1,344,891 barrels or 50 per cent.

"The total consumption of Portland cement in 1909 including Canadian and imported cement was 4,152,374 barrels, as compared with 3,134,338 barrels in 1908, an increase of 1,018,036 barrels or 32 per cent.

"Detailed statistics of production during the past three years have been as follows:—

——	1907.	1908.	1909.
	Barrels.	Barrels.	Barrels.
Portland cement sold	2,436,093	2,665,289	4,010,180
" manufactured	2,491,513	3,495,961	4,089,191
Stock on hand January 1	299,015	383,349	1,093,493
" December 31	354,435	1,214,011	1,172,504
Value of cement sold	$3,777,328	$3,709,063	$5,266,008
Wages paid	956,080	1,274,638	1,182,090
Men employed	1,786	3,029	2,411

"The average price per barrel at the works in 1909 was $1.31 as compared with $1.39 in 1908.

"The imports of Portland cement into Canada during the twelve months ending December 31, 1909, were 497,678 cwt., valued at $166,669. This is equivalent to 142,194 barrels of 350 pounds, at an average price per barrel of $1.17. The imports in 1908 were 469,049 barrels, valued at $531,045 or an average price per barrel of $1.13. The duty is 12½ cents per hundred pounds.

"As there is very little cement exported from Canada, the consumption is practically represented by the Canadian sales together with the imports.

"Following is an estimate of the Canadian consumption of Portland cement for the past five years:—

Calendar Years.	Canadian.		Imported.		Total.
	Barrels.	Per cent.	Barrels.	Per cent.	Barrels.
1905	1,346,548	59	918,701	41	2,285,249
1906	2,119,764	76	665,845	24	2,785,609
1907	2,436,093	78	672,630	22	3,108,723
1908	2,665,289	85	469,049	15	3,134,338
1909	4,010,180	97	142,194	3	4,152,374

QUEBEC MINING STATISTICS.

The PRESIDENT in calling upon Mr. T. DENIS, recently appointed to succeed Mr. J. OBALSKI, as Superintendent of Mines of Quebec, to present the mineral returns from that province, remarked that Quebec, in consequence of recent territorial additions, was now the largest province or State in North America, and from what was known concerning geological conditions, should become the leading mineral producing area of the continent.

Mr. DENIS then read the following statement:—

PRELIMINARY STATEMENT OF THE MINERAL PRODUCTION IN THE PROVINCE OF QUEBEC DURING THE CALENDAR YEAR OF 1909.

(Subject to revision)

	Quantity.	Value 1909.	Value 1908.
		$	$
1 Bog Iron Ore..... Tons	2,900	3,200	30,757
2 Ochres..... "	3,940	28,093	19,940
3 Chromite..... "	5,000	55,000	83,740
4 Copper..... "	35,000	130,000	159,588
5 Asbestos..... "	88,315	2,295,494	2,551,596
6 Asbestic..... "		20,322	
7 Mica.....lbs.	62,516	26,834	95,311
8 Phosphate..... Ton	45	445	1,610
9 Graphite.....lbs.	193,320	8,699	165
10 Mineral Waters..... galls.	32,537	17,246	.....
11 Slate.....	.....	24,000	20,056
12 Cement.....barrels	1,011,194	1,314,551	1,127,335
13 Magnesite..... Tons	330	2.508	520
14 Marble.....	.....	130,000	.....
15 Flagstone.....	.....	8,500	3,600
16 Granite.....	.....	149,064	250,000
17 Lime.....	.....	98,989	96,000
18 Limestone.....M.	.....	414,942	223,580
19 Bricks.....	89,901	512,521	525,000
20 Tiles and Pottery of Canadian clay (partly estimated).....	.....	100,000	270,000
* Estimated value of products not returned.....	84,409	84,400	.....
		5,424,808	5,458,998

* Made up of 5 % of value of products Nos. 16-17-18 and 10 % of value of No. 19.

The total value of the mineral production of the Province of Quebec for the calendar year ending December 31st, 1909, according to the returns received by the Bureau of Mines of the Province, amounted to $5,424,808. This is a slight decrease as compared with the previous year, the figures for which are given in an adjoining column.

Asbestos.—The total shipments of asbestos and asbestic during the year totalled 88,315 tons 2,000 lbs. valued at $2,315,816, as follows:

Crude asbestos.	Tons	3,298	$ 581,618
Mill stock	"	60,556	1,713,876
		63,854	2,295,494
Asbestic.	"	24,461	20,322
		88,315	$2,315,816

This is a slight decrease as compared with the shipments of the previous year, but is not to be taken as a decrease of activity of the industry. In fact one of the main causes of this lower figure has been that preparations were being made for a higher production in 1910. Several mills either curtailed their production or even stopped operations, during more or less extensive alterations and improvements for greater capacity. There are at the present time four new large mills in course of erection.

It sounds already like ancient history to mention that the great feature of the asbestos industry during the year 1909 has been the consolidation of various companies into two large corporations, viz., the Amalgamated Asbestos Corporation, Ltd., and the Black Lake Consolidated Asbestos Co., Limited. The Amalgamated Asbestos Corporation was formed with a capital of $25,000,000, to take over and operate the mines and mills of the following companies:—King's Asbestos Mines, Ltd., of Thetford; Beaver Asbestos Company of Thetford; British Canadian Asbestos Co., of Black Lake; Standard Asbestos Company, Ltd., of Black Lake; Dominion Asbestos Company, of Black Lake.

The Black Lake Consolidated Asbestos Company, Limited, was formed with a capital of $5,000,000 to take over the properties of the Union Asbestos Mine, Black Lake; the Black Lake Chrome and Asbestos Company, of Black Lake; the Dominion Chrome Company, of Black Lake; the Imperial Asbestos Company, of Black Lake. This amalgamation did not produce any asbestos during the year 1909, but they are at present erecting one of the largest mills of the district, which is expected to start operations in May.

The following companies made returns of production for the year 1909:—

Amalgamated Asbestos Corporation, Ltd., Thetford and Black Lake
Asbestos and Asbestic Company, Ltd., Danville.
Bell Asbestos Mines, Thetford.
Broughton Asbestos Fibre Co., East Broughton,
Eastern Townships Asbestos Co., Thetford.
Jacobs Asbestos Mining Co., Thetford.
Johnson's Asbestos Company, Thetford and Black Lake.
Ling Asbestos Company, East Broughton.
Robertson Asbestos Mining Co., Robertsville.

Mica.—The mica industry was very inactive during 1909, and the market for this product was unsatisfactory. At the prices offered by buyers the producers could not make ends meet, and as a result the figures of production are considerably below last year's.

Cement.—The production of cement in the Province of Quebec in 1909 shows a substantial increase as compared with 1908. This industry was also characterized by a consolidation of interests, national in scope. The Canada Cement Company took over the three largest plants in the Province of Quebec, as well as others in Ontario and in the western provinces. It is said that very substantial savings in freight and in management can be effected by the amalgamation, and the company claims that the consumer will derive benefit from such savings.

Other building materials.—These comprise building stones, lime, marble, bricks, tile and pottery manufactured from Canadian clay. It is, of course, very difficult to gather complete figures of production of these materials. In past years it has been the custom of the Quebec Bureau of Mines to adopt the figures given by the last Dominion census, but this year we made an attempt to get returns direct from the producers. The figures for 1909 are not, therefore, comparable with the production of the previous year. The results of our endeavour have been very gratifying, as will be seen by glancing over the table for 1909, which is compiled from direct returns. I must say, however, that our work in this respect has been considerably lessened by the use which we freely made of the lists of producers of stone, bricks, lime and pottery given in the Report on the Mining and Metallurgical Industries issued by the Mines Branch of Ottawa and of the lists compiled by Mr. McLeish, which are printed in leaflets.

ONTARIO MINERAL STATISTICS.

In the unavoidable absence of Mr. T. W. Gibson, Deputy Minister of Mines of Ontario, and on that gentleman's behalf, the President, Dr. W. G. Miller, briefly reviewed the Province's recent mining progress, pointing out that an increased production of silver, amounting to between five and six million ounces, had been made during 1909; that Ontario is now producing sixty-five per cent. of the nickel consumed by the world, and that conditions generally were most satisfactory. He also referred to the fact that Ontario now occupied the premier position among the mineral producing provinces of the Dominion.

PRODUCTION, 1909.

Product.		Quantity.	Value.
Metallic:—			
Gold	ounces	2,042	$ 32,445
Silver	"	25,737,037	12,382,689
Cobalt	tons	1,533	94,965
Nickel	"	13,907	2,709,798
Copper	"	7,933	1,127,015
Iron Ore	"	263,777	645,622
Pig Iron	"	407,013	6,101,528
Zinc Ore	"	895	8,950
			$ 23,303,012
Less value Ontario iron ore (220,307 tons) smelted into pig iron			537,549
Net metallic production			$ 22,765,463

PRODUCTION, 1909—*cont.*

Product.		Quantity.	Value.
Non-Metallic:—			
Arsenic, refined	tons	885	$ 61,039
" crude	"	4,599	.....
Brick, common	No.	246,308,000	1,916,147
Tile, drain	"	27,418,000	363,550
Brick, pressed	"	53,166,941	490,571
" paving	"	4,067,620	73,700
Building and crushed stone		.....	459,730
Calcium carbide	tons	2,349	151,676
Cement, portland	bbls.	2,303,263	2,897,348
Corundum, grain	tons	1,508	140,817
Feldspar	"	11,001	36,204
Graphite, refined	"	730	37,624
Gypsum, crude	"	11,488	23,604
Iron pyrites	"	28,946	78,170
Lime	bush.	2,633,500	470,858
Mica	tons	350	73,124
Natural gas		.....	1,188,179
Peat fuel	tons	60	240
Petroleum	Imp. gals.	14,723,105	559,478
Phosphate of lime	tons	272	1,904
Pottery		.....	43,214
Quartz	tons	63,172	75,329
Salt	"	77,490	389,573
Sewer pipe		.....	311,830
Talc	tons	4,350	8,700
Non-metallic production		.....	$ 9,852,609
Add net metallic production		.....	22,765,463
Total production		.....	$ 32,618,072
Total for 1908		.....	$ 25,637,617

Silver:—The output of silver, 25,737,037 ounces, as compared with the year 1908, shows an increase of 6,292,637 ounces, or an advance of nearly one-third. The total yield of the Cobalt Camp, from which practically the entire production of silver now comes, for the six years since the mines were opened, amounts to 63,258,220 ounces, having a money value of $32,811,399.

The limits of the valuable area at Cobalt proper now appear to be pretty well defined; but the outlying camps of South Lorrain, Elk Lake and Gowganda are beginning to ship out ore.

A development in the practice at Cobalt is the extensive adoption of concentration processes for low-grade ore. At the

end of the year nine concentrators were in operation and four others were in course of construction.

Nickel:—As in silver, 1909 is the record year for production of nickel. The mattes turned out by the Canadian Copper Company and Mond Nickel Company contained a total of 13,141 tons of nickel as compared with 9,563 tons in 1908. Adding the estimated nickel contents of the ores from Cobalt, the total production of nickel reached 13,907 tons, much the largest production in the history of the industry. The deposit of nickel ore discovered in 1908, in Dundonald township, west of the T. & N. O. Railway, has not yet been worked in a commercial way, but the fact that the pyrrhotite in this neighborhood is nickeliferous is significant, and it may be that other bodies of workable size will yet be located.

Copper:—The bulk of the copper in Ontario continues to be raised from the mines of the Sudbury District. Last year there were 7,873 tons of copper contained in the bessemerized mattes produced there, the total production of copper being 7,933 tons. The yield in 1908 was 7,561 tons.

Gold:—The production of gold in Ontario fell last year to 2,042 ounces, most of which came from the Laurentian Mine, Lake Manitou, but considerable interest is being taken in the discoveries of gold in the neighborhood of Porcupine Lake, which were made last summer. This new field is situated in the townships of Whitney and Tisdale, north of the height of land between Hudson Bay and the Great Lakes, and about thirty-two miles west of the T. & N. O. Railway. The gold is found in quartz veins from three feet to twenty-five feet and upwards in width. Free gold in some of these veins shows freely at the surface, and if values continue in depth a new gold camp will be opened up.

Non-Metallic Minerals:—The yield of crude petroleum is steadily diminishing, being 14,723,105 imperial gallons in 1909 as against 18,479,547 gallons in 1908. The older fields of Lambton County are declining in production, and so also are the wells in the newer districts of Tilbury and Romney.

On the other hand, the yield of natural gas continues to increase, in 1909 having a value of $1,188,179 as against $988,616 in 1908.

The Portland Cement industry continues to expand, the output being 2,303,263 barrels as compared with 2,022,877 barrels in the previous year.

Quartz, feldspar, iron pyrites, gypsum and corundum are the basis of minor industries which are rapidly assuming considerable dimensions, while salt, mica, talc and graphite were raised in about the same proportions as in former years.

Building material, such as brick, lime and stone were as usual to be produced in large quantities.

Phosphate of Lime is again showing in the list of mineral products, after an absence of a number of years.

It should be borne in mind that the valuation of the mineral production in Ontario by the Bureau of Mines is based on the value of the raw materials, or of the products as they leave the country. If, for instance, the metals were computed at their refined prices, the value of $32,618,072 for 1909 would be increased by six or seven millions of dollars. As it is, the figures show an advance of $7,000,000 over the output for 1908.

RETURNS FROM OTHER PROVINCES.

The SECRETARY then presented returns from the Provinces of Nova Scotia, Alberta and British Columbia, prepared by respectively Mr. Hiram Donkin, Deputy Commissioner of Lands and Works, Halifax, N. S.,; Mr. Robert Livingstone, Provincial Inspector of Mines, Edmonton, Alta; and Mr. E. Jacobs, Victoria, B.C. These returns are appended.

MINING IN NOVA SCOTIA, 1909.

Coal.—The output of coal for the Nova Scotia fiscal year of 1908 was 6,299,282 tons and for 1909 was 5,216,714, a decrease of something over a million tons.

Of this decrease about 660,000 tons is attributable to a strike which seriously affected two of the largest coal producers in the Province and has, since the 10th of August last, completely closed down a third, but this colliery will likely be again producing in two or three months.

In addition to the loss of output due to the strike there were large quantities at the close of 1908 held in stock, as is usual at this time of the year, at Montreal, Three Rivers, Quebec and else-

where; this surplus was drawn upon by reason of shortage in output and not replaced at the close of 1909.

The outlook for the present year is encouraging and if no strike occurs the production will not be much short of the production for 1908.

Gold.—The production of gold for the year was 12,600 ounces, recovered from 59,000 tons of ore mined and crushed, which is a slight increase over the production of the year 1908. Actual mining operations were carried on in nineteen districts, and prospecting and development work at eight or ten additional districts.

Iron.—The production for the year was 12,000 tons. The Canada Iron Corporation, which has taken over the properties of the Londonderry Iron and Mining Company, did not mine either at Londonderry or East Mines, and the only ore raised by them was the 12,000 tons before referred to, from development work at Torbrook, where this company is making preparations for very extensive operations. They have just about completed a surface equipment capable of handling from 600 to 1000 tons of ore a day, and they are hastening development work underground on what is known as the hematite vein.

Copper.—No copper has been shipped. Three companies have been engaged in prospecting and development work, namely: The Lake Copper Company at Lochaber; The Briley Brook Copper Company at Briley Brook, both in Antigonish County, and the Maritime Exploration Company at Three Mile Brook, Pictou County.

Antimony.—The property of the Dominion Antimony Company at West Gore, which has been idle for the past eighteen months, has lately been acquired by the St. Helen's Smelting Company of Swansea, Wales, who are now engaged in preparatory work to the re-opening of the mine.

Tungsten.—At Moose River, Halifax County, where a number of very promising Scheelite bearing veins were opened up last year, prospecting has been continued and additional veins uncovered. Present indications point to a very bright future for this property.

Gypsum.—The production of 300,000 tons shows quite a large increase over the production of the year 1908. Several new com-

panies are about to commence operations and indications point to a still larger production during the coming year.

Building Stones.—The operators of the different quarries throughout the province report a very dull year, and the production of 20,000 tons is very much below the average.

Bricks and Drain Pipe.—The bricks manufactured were 22,000,000 and drain pipe 300,000 feet. This industry shows practically no change over the year 1908.

Coal raised, gross tons		5,216,714¼
Pig Iron	" "	307,320
Iron Ore	net tons *	678,050
Limestone	" "	290,440
Coke made	" "	501,000
Gypsum, gross tons		300,000
Gold, ounces		12,600
Bricks		22,000,000
Drain Pipe	feet	300,000
Building Stones	net tons	20,000
Moulding Sand	" "	330

* Includes 12,000 tons mined in the Province, the rest imported.

ALBERTA MINING RETURNS, 1909.

Statistics.

Number of new mines opened	32
Number of mines operated during the year	121
Number of tons of coal mined	2,174,329
Number of tons of coke produced	87,812
Number of tons of briquettes produced	89,785
Average number of men employed	5,207
Number of fatal accidents inside the mines	7
Number of fatal accidents outside the mines	2
Number of non-fatal accidents inside the mines	47
Number of non-fatal accidents outside the mines	13
Number of mine managers' certificates issued	27
Number of pit boss certificates issued	23
Number of fire boss certificates issued	44

The output of coal for the year 1909 may be classified as follows:—

Bituminous	1,197,399	tons
Lignite	763,673	"
Anthracite	213,257	"

The following is a comparison of the production of coal, coke and briquettes for the years 1908 and 1909:—

Coal.

1908	1,845,000	tons
1909	2,174,329	"

Increase, 329,329 tons, or 17.85%.

Coke.

1908	75,657	tons
1909	87,812	"

Increase, 12,155 tons, or 16.07%.

Briquettes.

1908	36,261	tons
1909	89,785	"

Increase, 53,524 tons, or 14.76%.

Table showing Coal production since 1901.

(Note—1901 to 1904 inclusive show outputs for the whole of the North-West Territories, Alberta and Saskatchewan, and 1905 to 1909 inclusive, for Alberta only).

1901	346,649	tons
1902	510,674	"
1903	622,939	"
1904	782,931	"
1905	811,228	"
1906	1,385,000	"
1907	1,834,745	"
1908	1,845,000	"
1909	2,174,329	"

Increase in output for 1909 over output for 1905 (5 years), 168.03%.

Number of tons of coal mined per fatal accident, during 1909	241,592
Number of men killed per million tons mined	4.14
Number of men killed per each thousand men employed	1.73

Development during the year.—The development work at nearly all the mines operating in the Province has been very active during the year. In the lignite field, at least five collieries, which will be large producers in the future, have passed the initial stages of developments, and the same number in the bituminous field have opened up their main tunnels, secured railway connections and installed their plants.

Prospect Work.—Prospecting work has also been very active and at least two large additional coal areas in the bituminous field have been proven, viz:—the Brazeau Field west of Edmonton, contiguous to the line of the G. T. P. Railway, and the South Fork field, south of the Crow's Nest Branch of the C. P. Railway south-west of Frank. Sufficient prospect work has been done in the latter district to demonstrate that this coal area is larger and will eventually be more important than the field which is now being operated in the Frank-Coleman District.

Trade Conditions.—The coal trade has been very brisk during the year and the demand for Alberta coal is rapidly increasing. During the early part of the year a dispute arose between the operators and their workmen which had the effect of shutting off approximately 75 per cent of the total coal production of the Province for a period of three months; but an agreement is now in force which will in a measure guarantee the steady operation of the mines throughout the Province at least until April 1st, 1911, and indications point to a very considerable increase in the production of coal during the coming year.

Wages.—The scale of wages paid in the Province during 1909 was practically the same as that paid during the two previous years.

The general wage schedule for day labour is as follows:—

Inside Men.

Fire Bosses	$85.00	to	$110.00	per month.	
Shotlighters	3.00	to	3.50	per day.	(8 hrs.)
Bratticemen			3.00	"	" "
Bratticemen helpers			2.50	"	" "
Timbermen			3.00	"	" "
Timbermen helpers			2.75	"	" "
Drivers			2.75	"	" "
Drivers, wet places			3.00	"	" "
Team Drivers			3.00	"	" "
Tracklayers			3.00	"	" "
Tracklayers' helpers			2.75	"	" "
Rock Miners			3.50	"	" "
Miners			3.00	"	" "
Miners, wet places			3.50	"	" "
Locomotive Engineers			3.00	"	" "
Switchmen			2.75	"	" "
Chute Loaders			2.75	"	" "
Labourers			2.50	"	" "
Timber handlers			2.75	"	" "
Machine men			3.50	"	" "
Machine men helpers			3.00	"	" "
Switch boys			1.50	"	" "
Door boys			1.50	"	" "
Hoistmen			3.00	"	" "
Rope riders			2.75	"	" "
Couplers, boys			1.50	"	" "
Couplers, men			2.50	"	" "
Pushers	2.75	to	3.00	"	" "

Outside Men.

Pitheadmen	$2.50	per	day	(10	hrs.)
Dumpers	2.50	"	"	10	"
Slate pickers, men	2.00	"	"	10	"
Slate pickers, boys	1.25	"	"	10	"
Car oilers, boys	1.25	"	"	10	"
Car oilers, men	2.00	"	"	10	"
Tally boys	1.25	"	"	10	"
Teamsters	2.50	"	"	10	"
Blacksmiths	3.50	"	"	10	"
Blacksmiths' helpers	2.50	"	"	10	"
Mine carpenters	3.50	"	"	10	"
Mine carpenters' helper	2.50	"	"	10	"
Car repairers	3.00	"	"	10	"
Power House Engineers	3.50	"	"	12	"
Tipple Engineers	3.25	"	"	10	"
Locomotive Engineers	3.25	"	"	10	"
Locomotive Engineers' helpers	2.80	"	"	10	"
Firemen	2.50	"	"	8	"
R. R. car handlers	2.40	"	"	10	"
Fanmen	2.50	"	"	12	"
Outside labourers	2.25	"	"	10	"
Fan fireman	3.00	"	"	12	"
Lampmen	2.50	"	"	12	"
Machinists	3.20	"	"	10	"
Machinists' helpers	2.50	"	"	10	"
Couplers	2.25	"	"	10	"
Sawyer	3.00	"	"	10	"

MINERAL PRODUCTION OF BRITISH COLUMBIA IN 1909

The mineral production of British Columbia in the calendar year 1909 is shown in some detail in the accompanying tables. The figures* are subject to revision when the final returns for the year shall have been received, for the information upon which this review is based was obtained five or six weeks before the end of the year. The production for the months of November and December, consequently, had to be estimated. Similarly, the prices at which the value has been calculated are subject to change, since those used were New York average prices for ten months, to October 31, as shown by "*Engineering and Mining Journal*" quotations. It is now estimated, though, that the net outcome of calculations at the average prices for the full year will be to add approximately $30,000 to the total value of production as exhibited in the tables herewith. Quantities of minerals will also be changed from the round-figure approximate amounts to precise figures giving actual production, but no very material change is looked for in this particular, much care having been taken in gathering information relating to the output of practically all the more important mines in the province.

The net increase in value of the production of 1909 as compared with that of 1908 is estimated at $575,223. For the better appreciation of the increase it should be borne in mind that the prices at which metals have been calculated for the years 1909 and 1908, respectively, are as follows, those in brackets showing (where there was any difference between the figures for the two years) those used in arriving at the value for 1908: Gold, placer, $20 per ounce; gold, lode, $20.67 per ounce; silver, 49 (50.2) cents per ounce; lead, 3.8 (3.78) cents per pound; copper, 12.9 (13.2) cents per pound; zinc, 5 cents per pound; coal, $3.50 per long ton; coke, $6 per long ton. Silver is less 5 per cent and lead 10 per cent of the New York average market prices. For coal and coke prices are those generally ruling in the province.

The first exhibits quantity and value of the mineral production in 1909, and, for purpose of comparison, that for 1908 also:

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* The figures given in the following tables are from the official returns. Mr. Jacobs' original estimates were, however, very approximately correct.

QUANTITY AND VALUE OF MINERAL PRODUCTS FOR 1908 AND 1909.

Mineral Product	Customary Measure	1908		1909	
		Quantity	Value	Quantity	Value
Gold, placer	Ounces	32,350	$ 647,000		$ 477,000
Gold, lode	Ounces	255,582	5,282,880	238,224	4,924,090
Total gold	Ounces	287,932	$ 5,929,880	280,000	$ 5,401,090
Silver	Ounces	2,631,389	1,321,483	2,532,742	1,239,270
Lead	Pounds	43,195,733	1,632,799	44,396,346	1,709,259
Copper	Pounds	47,274,614	6,240,249	45,597,245	5,918,522
Zinc	Pounds		270,000	10,000,000	400,000
Total metallic			$15,394,411		$ 14,668,141
Coal	Tons of 2240 lb.	1,677,849	5,872,472	2,006,476	7,002,666
Coke	Tons of 2240 lb.	247,399	1,484,394	258,703	1,552,218
Building materials, etc.			1,100,000		1,200,000
Total value of production			$32,851,277		$24,443,025

The proportions of value of production credited to the several mining divisions and districts, respectively, are as under :—

PRODUCTION OF MINERAL BY DISTRICTS AND DIVISIONS.

Name	Divisions		Districts	
	1908	1909	1908	1909
CARIBOO DISTRICT			$ 405,000	$ 247,000
Cariboo Mining Division	$ 355,000	$ 220,000		
Quesnel Mining Division	30,000	12,000		
Omineca Mining Division	20,000	15,000		
CASSIAR DISTRICT			298,234	234,498
EAST KOOTENAY DISTRICT			4,802,680	4,766,215
WEST KOOTENAY DISTRICT			5,448,224	5,169,749
Ainsworth Mining Division	422,181	617,340		
Nelson Mining Division	462,836	584,955		
Slocan and Slocan City Mining Divisions	676,580	954,737		
Trail Creek (Rossland)	3,713,392	2,875,584		
Other parts	173,235	137,633		
LILLOOET DISTRICT			13,779	16,676
YALE DISTRICT			7,649,963	7,728,256
Osoyoos, Grand Forks and Greenwood Mining Divisions	7,545,380	7,501,046		
Similkameen and Nicola	101,583	225,210		
Yale Mining Division	3,000	2,000		
COAST DISTRICT (Nanaimo, Alberni, Clayoquot, Quatshuatsions, Victoria)			5,233,397	6,280,631
Totals			$23,851,277	$24,443,025

Brief Review of Progress and Prospects in British Columbia.—In briefly reviewing the progress made in 1909 and the prospects for 1910 it is noted that generally speaking the mining and metallurgical industries of the province are in a condition believed to warrant the conclusion that more progress was made in 1909 than is indicated by the comparatively small increase in total value of mineral production during the year, and that there are good grounds for expecting a substantial increase in output of minerals in the year just entered upon.

More placer gold should be recovered in both Cariboo and Atlin districts, preparations for enlarged hydraulicing operations making a bigger output probable. Lode gold may be expected to show an increase from both milling and smelting ores. Hedley camp, in the Similkameen district, and Sheep Creek, in Nelson mining division, should contribute the former, and the Boundary district the latter.

Silver and lead will probably be produced in larger quantity this year in East Kootenay and as well in the Ainsworth and Slocan divisions of West Kootenay. In the first-named, work was recently resumed at the Sullivan Group, while developments on the North Star and neighbouring Stemwinder also promise increased production. It is notewothy that the production of silver and lead in Ainsworth and Slocan was considerably larger in 1909 than in 1908. The totals for the two years are, in round figures: Silver: In 1909, 1,500,000 ounces, as compared with 1,163,000 ounces in 1908; lead: In 1908, 17,460,000 pounds, as against 11,362,000 in 1908. Portland Canal, in northern British Columbia, will shortly commence production of silver and lead, the Portland Canal Mining and Development Company having built and equipped a concentrating mill to treat silver-lead ore from its mine there. The Dominion Government bounty on lead was payable throughout 1909, and lead producers received about $340,000 from this source.

Preparations are being made for mining iron ores on the Coast. Zinc, both ore and concentrate, is being produced on a commercial basis in Ainsworth and Slocan divisions, and the outlook is favourable for an appreciably large production in 1910. The mining of scheelite ore in Cariboo may be looked for this year.

Coal mining is flourishing, and the demand for coke is larger than at any previous time since smelting was commenced in the

province. The old coal mines on Vancouver Island and in the Crow's Nest Pass have a ready market for all the coal they have facilities for mining, while the new collieries—on Vancouver Island, in Nicola Valley, at Princeton, Hosmer and Corbin and in the Crow's Nest Pass—have each found buyers for the product of their respective mines.

Structural materials and clay products are being used in increasingly large quantities. The coast cities in particular require much building material. In the Kootenay a noticeable development is that of marble-quarrying at Marblehead, situated a few miles north of Kootenay Lake.

Enlargements of milling, concentrating, smelting, and refining works, have been fairly general. In particular the additional copper smelting capacity added at the Granby Company's works, Boundary district, and the Consolidated Company's smeltery at Trail, West Kootenay, denote an intended considerable increase in production of copper. The Tyee Copper Company, too, has added to its copper smelting facilities at Ladysmith, Vancouver Island. The increase in capacity of lead smelting furnaces and electrolytic refining tanks at Trail, shows that a larger production of pig lead is also being provided for.

Progress is further demonstrated by important additions to power and other machinery at mines and reduction works. Electric power transmission lines have been extended in the Boundary. Railway transportation has been established in several parts of the province where mining had previously lacked this essential to progress. Viewing the mining industry situation as a whole, it is evident that a distinct advance was made in British Columbia in 1909, and that the outlook for 1910 is decidedly favourable to progress in larger degree.

WEDNESDAY AFTERNOON SESSION.

The members re-assembled at three o'clock.

A paper contributed by Mr. J. D. KENDALL, of London, England, and entitled "MINING ENGINEERS AND MINING INSTITUTES," was read by the Secretary, who, commenting thereon, said: "The point raised by Mr. Kendall in a measure, anticipates the proposals put forward by the 'By-law Committee,' to raise the

standard of Institute membership and which will no doubt be considered and discussed at another session. It may be remarked, however, that during the past two or three years the Council has in general insisted on technical qualification or practical experience as a condition of membership, and the result has proved distinctly beneficial.

"At the same time the provisions of the present by-law are manifestly vague and indefinite, and so long as they remain so it is difficult for the Council to adopt and follow any regular or settled rule of conduct in dealing with applications."

The PRESIDENT.—"This is a decidedly important question. During the last two years I have fully realized that in the classification of candidates for membership we have not been governed by any fixed principle. Thus it may easily happen that in case of two candidates of equal standing, one, because he may be well-known to members present at a Council meeting will be elected to full membership, while the other, not being known to the Council, will be given rank as an associate only. Hence there is occasion for a change in this respect. However, to give expression to my personal views, I firmly believe that the conditions for membership in the Canadian Mining Institute should be as broad as possible; that this membership should include not only technical men, but all others directly or indirectly interested in the business or industry of mining; and that if there is a need for a strictly technical organization then other arrangements may be made accordingly."

Other papers read and discussed during the afternoon were: "THE NECESSITY OF DISTINGUISHING BETWEEN PROSPECTING, DEVELOPING AND MINING" by Mr. R. W. BROCK, Director of the Geological Survey of Canada; the HELEN MINE, MICHIPECOTEN, ONT., by R. W. SEELYE, read in the absence of the author, by Mr. L. L. Bolton; The IRON ORE RESOURCES OF THE BRITISH PACIFIC COAST, by E. LINDEMAN; and MINING LITERATURE, by ALLAN GREENWELL, Editor of the *Colliery Guardian*, London, read in the absence of the author by Mr. Frederick Hobart.

WEDNESDAY EVENING.

At eight o'clock an interesting address, illustrated by lantern slides was delivered by Mr. P. Mc.N. BENNIE, of Niagara Falls,

N. Y., on "RECENT DEVELOPMENTS IN ELECTRO-SIDERURGY." Introducing his subject, Mr. Bennie said: "I am very glad to have this opportunity of giving here a resumé of recent progress in 'Electro-Siderurgy.' I have been asked to explain the meaning of the term 'Siderurgy.' Well, it is an old English word applicable to the manufacture of iron and steel, and its use in the present instance appeared to me to be appropriate.

"To proceed, however, I may now announce that Electro-Siderurgy has now passed the stage of laboratory experiment. We are now in the field. (Applause). It was at one time said that the electric furnace had a future. It has something worse than that. It has a past. (Laughter). We have removed the cloak of experimentation, and now stand revealed, we believe, garbed in the royal purple of accomplishment."

At the conclusion of Mr. Bennie's address, Prof. H. E. T. HAULTAIN, in moving a vote of thanks said: "I wish to express my sincere appreciation of the very able paper Mr. Bennie has presented to us to-night. He has attended the Institute meetings year after year, and has kept us fully informed concerning the progress of the science with which he has identified himself. The relation of facts and figures appertaining to experimentation or research are usually of interest only to those directly concerned; but Mr. Bennie's presentation of the subject has been so happy and lucid that he has admirably succeeded in holding the attention of hearers, the majority of whom had no personal nor direct interest in Electro-metallurgy.

"He has led us along blazed trails into a new region—a region that we must be prepared to enter. At present we appear to approach this new land somewhat timorously. We have either technical or financial qualms; but conditions are nevertheless surely forcing us to follow in the direction Mr. Bennie would have us travel.

"Another matter that has impressed me is the remarkable absence of 'Bennie' in that gentleman's papers. He has told us what other people are doing; but it seems to me that a man who shows himself to be so thoroughly familiar with all that is going forward, must also be playing an active and useful part in the movement. Mr. Bennie tells us that the experimental stage of electro-metallurgy has been passed. Still, I have no doubt that he

himself is now engaged in a field of delightful tentative enterprise, and I am sure we shall all appreciate it very much if at some future time he will afford us an opportunity of learning something of his own endeavours in this direction." (Applause).

Dr. J. B. PORTER in seconding the resolution, said: "As Professor Haultain has expressed the appreciation of the meeting so admirably, I have merely to endorse his remarks. The great progress of electro-metallurgy in recent years, is, however, also a matter of congratulation.

"It is not so long ago since Mr. Bennie first addressed the Institute on this subject; nevertheless at that time electro-metallurgical science was quite in its infancy. To-night we have been shown on the screen photographs of relatively large electrical furnaces actually in successful operation. I doubt whether any other branch of metallurgy has made so rapid an advance."

Mr. BENNIE here announced that his partner and himself had lately devoted themselves in particular to the study of the electric smelting of zinc, and that as a matter of fact, experiments recently conducted by the former on a commercial scale in Germany had proved eminently successful. He added that he hoped at the next meeting of the Institute to give the particulars of a process providing for the economical extraction of zinc from sulphide ores in the electric furnace.

Dr. ALFRED STANSFIELD, of McGill University, Montreal, then read a paper entitled "TOOL STEEL DIRECT FROM THE ORE IN AN ELECTRIC FURNACE," having special reference to the experimental work undertaken by Mr. J. W. Evans, of Belleville, Ontario. At the conclusion of the paper, Prof Haultain in moving a resolution expressing sympathy with Mr. Evans, who by reason of serious illness was unable to be present, paid a high tribute to that gentleman's ability and enterprise. The resolution, which read as follows, was unanimously adopted:

"That this meeting of the Canadian Mining Institute desires to express its appreciation of the results achieved by J. W. Evans in his electric furnace, and regrets that his illness prevented his attendance on the present occasion."

THURSDAY MORNING SESSION.

The session from 10 a.m. to 1 p.m. was devoted to the reading and discussion of the following papers:

"COMMENTS ON THE ORIGIN OF ASBESTOS," by Dr. A. E. BARLOW, Montreal; "THE DISTRIBUTION OF CHROMITE AND ASBESTOS DEPOSITS OF THE EASTERN TOWNSHIPS," by JOHN A. DRESSER, Ottawa; and "CRITERIA OF DOWNWARD SULPHIDE ENRICHMENT," by F. L. RANSOME, U. S. Geological Survey, Washington, D. C.

THURSDAY AFTERNOON SESSION.

A major part of the afternoon session was devoted to a consideration and discussion of the proposed amendments to the By-laws. The following proposals were adopted:

AMENDMENTS TO BY-LAWS.

(6). "EX-OFFICIO HONORARY MEMBERS.—The Directors of the Mines Branch and of the Geological Survey Branch of the Federal Department of Mines shall be ex-officio honorary members of the Institute during their tenure of office."

(7). "EX-OFFICIO MEMBERS.—The principal officers of the Mines Branch and the technical officers in charge of field parties of the Geological Survey Branch of the Federal Department of Mines, may be elected ex-officio members of the Institute. After election they shall remain ex-officio members during their tenure of office."

(13). "ANNUAL SUBSCRIPTION.—The annual subscription for members and associates shall be ten dollars, and from student members two dollars, payable in advance on the first day of January in each year. Subscriptions remaining unpaid on April 1st of each year may be subject to sight draft made by the Treasurer."

(14). "Members of the Institution of Mining and Metallurgy, non-resident in Canada, and vouched for by the Secretary of the Institution of Mining and Metallurgy, may become members of the Institute upon payment of an annual fee of five dollars."

(24). "OFFICERS AND COUNCIL.—The Vice-Presidents shall hold office for two years; two of them shall retire annually, but shall be eligible for immediate re-election."

(35). "MEETINGS.—Regular meetings of Council shall be held in October, December, January, February and April of each year on dates to be determined by the President. The October, January and April meetings shall be held at headquarters. The December and February meetings may be held elsewhere, if in the opinion of the Council this is desirable.

"Special meetings of Council may be called by the Secretary on a written requisition from the President or six members of Council at such places or times as may be deemed desirable."

COPPER MINING IN THE EASTERN TOWNSHIPS.

Dr. JAMES DOUGLAS, of New York, then delivered an interesting address, on the subject of copper mining in the Province of Quebec, in the course of which he gave some reminiscences of his experiences in connection with early efforts at Harvey Hill and elsewhere.

Mr. JOHN E. HARDMAN voiced the sentiments of the meeting by expressing appreciation of Dr. Douglas' remarks. He said: "Speaking for the members of the Institute resident in the Province of Quebec, I feel we are very much indebted to Dr. Douglas for his kind words this afternoon. His hopeful expression of opinion concerning the possibilities of the copper industry of the Eastern Townships is also most gratifying. We all, of course, recognize Dr. Douglas' eminence as a copper metallurgist, and his opinions therefore on this subject must necessarily carry the greatest possible weight.

"At one time I was very sceptical concerning the copper resources of the Province; but about five years ago, having been engaged in a professional capacity to make certain investigations, I had an opportunity of forming an opinion from personal observation; and I may say that I was astonished at the extent, number and promising character of the deposits contained in an area of approximately forty square miles in the Eastern Townships."

THURSDAY EVENING.

At 8 o'clock, Dr. J. D. IRVING, Professor of Economic Geology at the Sheffield Scientific School of Yale University, New Haven,

Conn., and Editor of "*Economic Geology,*" delivered an interesting lecture, illustrated with lantern slides, on the subject of "THE FORMATION OF ORE DEPOSITS BY REPLACEMENT." At the conclusion of the lecture a hearty vote was tendered Dr. Irving.

SMOKING CONCERT.

The remainder of the evening was devoted to a smoking concert, at which Mr. G. G. S. LINDSEY, K. C., most efficiently presided. The programme, the arrangements for which were undertaken by Mr. W. E. H. CARTER, was an admirable one and the concert was thoroughly enjoyed by a large audience. A feature of the evening was the presentation of a handsome silver inkstand to Major R. G. Leckie, the "Dean" of the Institute. The presentation was made by Mr. J. STEVENSON BROWN, on behalf of the subscribers, who desired to thus express their appreciation of Major Leckie's long association and interest in the Institute.

FRIDAY MORNING SESSION.

The session opened at 10.30 a.m., with the presentation of a short paper by Prof. H. E. T. HAULTAIN, entitled "A WET SAMPLE CUTTER," descriptive of a simple device designed by the author for sampling, by the wet method, to explain which a working model was exhibited.

Prof. ROBT. H. RICHARDS, of the Massachusetts Institute of Technology, Boston, then delivered an instructive and illuminating address on the text "SOME DIRECTIONS IN WHICH IMPROVEMENTS IN CONCENTRATION MAY BE LOOKED FOR."

A vote of thanks to Prof. Richards was moved by Mr. HARDMAN, who said: "I do not think it would be either seemly or opportune at the present time to attempt to discuss Prof. Richards' able and valuable paper. To do so intelligibly one would wish first to study the address at leisure. That conclusion should not, however, debar us from expressing our very sincere thanks to Prof. Richards for his thorough presentation of a subject on which he is a recognized authority. The paper will be of the greatest practical value to engineers in Canada, for in this country we have many complex ores requiring treatment by wet concentration methods.

In short, it seems to me that Prof. Richards' paper is practically an epitome of the art of concentration, while it contains so many new ideas and explains so many new devices that its publication in the Institute's transactions will be invaluable for reference purposes to those of us who are called upon to solve problems in concentration practice. I should like to be permitted, therefore, to present the thanks of the Institute to Prof. Richards for the very able, very instructive, and altogether unique paper he has presented at this meeting."

Dr. PORTER, in seconding the resolution, said:–"As one who has been engaged for many years in teaching the science of ore-dressing, and has also made. I hope, a critical study of the subject, I desire also to add my testimony in support of Mr. Hardman's remarks. For two generations students of ore-dressing have been told, with truth, that Rettinger, the great Austrian, was the father of ore-dressing, and until very recently we have been able to regard him as the great authority on the subject, for, in spite of the large number of experimenters and students, Rettinger's work has remained the basis of our knowledge of ore-dressing.

"As is well known Prof. Richards has made the subject of ore-dressing a life-long study. Recently his work has come to fruition, and it seems to me no exaggeration to say that the mantle of Rettinger has fallen on Richards. But when one considers that Richards' work is that of a single individual, the advance in knowledge as a result of his experiments and investigations is perfectly amazing.

"Particularly as a teacher and also as a practitioner of ore-dressing, I wish to express my appreciation of Dr. Richards' very remarkable and unique work." (Applause).

THE PRESIDENT:—We all, I am sure, agree with what Mr. Hardman and Dr. Porter have said concerning Prof. Richards' great abilities, and we are very much indebted to Prof. Richards for his kindness in attending this meeting, and for his interesting address.

FRIDAY AFTERNOON SESSION.

The members re-assembled at 2.30 o'clock in the Banquet Hall of the hotel. During the afternoon the following papers were read:

"METHODS OF MAKING A LARGE SCALE CONTOUR SURFACE PLAN OF MINING CLAIMS," by W. H. BOYD, Ottawa.

"THE PORTLAND CANAL REGION," by R. W. THOMSON, Toronto.

"REMARKS UPON TWO WELL KNOWN MINES," by BENJAMIN B. LAWRENCE, New York.

"THE CLAYS OF NOVA SCOTIA," by Dr. H. RIES, Ithaca, N. Y.

The PRESIDENT, in introducing Mr. Lawrence (one of the official guests of the Institute) to the meeting, said: "At several former Annual Meetings of this Institute, we have been honoured by the presence of Dr. J. F. Kemp. To-day we have with us another representative of Columbia University, in the person of Mr. B. B. Lawrence, who was the first to be appointed a member to represent the Alumni on the Board of Trustees of that distinguished seat of learning."

Mr. LAWRENCE—While I have given to my paper the title, "Remarks upon Two Well Known Mines," as a matter of fact this should have been worded, "Remarks upon Two Mines that should be well known." (Laughter).

An interesting discussion, in which Dr. Douglas, Prof. Richards, Dr. Irving, Mr. Dresser, and Mr. Coste participated, followed the reading of Mr. Lawrence's paper, after which, the President in calling upon Dr. Ries to present his paper on "The Clays of Nova Scotia," remarked that the Institute possessed a very good friend in that gentleman. He added:

"Some call him an economic geologist, but since he has been specializing on clay, the clay workers have another name which they apply to him. They call him a 'mud geologist.' (Laughter). But we shall always remember this economic geologist of Cornell for his heroic achievements on the Trans-Canada Excursion in 1908. Those of us who were in Calgary when our friend Burn's steer ran amuck, will not forget that it was Dr. Ries who headed off that steer, and saved a great many lives of men who were vainly endeavouring to scale the barbed-wire fence. (Laughter).

"Dr. Ries has been most good in so regularly attending our annual meetings and we are more than delighted that he should be with us today. We propose making a Canadian of him in due time. In the United States Dr. Ries is regarded as the acknow-

ledged authority on clay, and there whenever they want clays worked up he is called on to lend assistance; but last year he came to Canada to investigate the clay resources of Nova Scotia. I have then much pleasure in requesting Dr. Ries to address you on that subject." (Applause).

Dr. RIES:—"The President, as we know, delights to commend the achievements of others, but is always too modest in alluding to his own exploits. It is only fair, however, that I should be permitted to return his compliment and I have to assure you that in your president you have one of the champion sprinters of Canada. When that steer to which he has referred was making his gallant charge, Dr. Miller accomplished a record 100 yards to reach the nearest telegraph pole. (Laughter).

"By way of preface to my paper, I may remark that the Dominion of Canada is a rather large consumer of clay products. The value of the clay products consumed annually in Canada represents something like five or six million dollars, and less than fifty per cent. of those products are made in Canada. The greater proportion is imported. The question, therefore, we have to consider is whether the Dominion does not possess clay resources of the particular quality suitable for the manufacture of those products which are now imported?"

A vote of thanks was accorded Dr. Ries for his paper, which was productive of an interesting discussion.

ELECTION OF OFFICERS AND COUNCIL.

At the request of the President, Mr. Frederick Hobart, on behalf of the scrutineers of the ballots cast for the election of officers and Council for the year 1910-11, reported as follows:

"The scrutineers appointed by the Institute to count the ballots for the various offices, which now become vacant, report respectfully that 175 ballots were cast, of which ten were rejected for informality—lack of signatures and other reasons. We have to report further that Dr. Frank D. Adams, of Montreal, is unanimously elected president of the Institute for the ensuing year; that A. B. W. Hodges, of Grand Forks, B. C., and R. W. Leonard, of Cobalt, Ont., are unanimously elected vice-presidents; and that, as a result of the voting the following gentlemen are elected councillors

of the Institute: Arthur A. Cole, of Cobalt, Ont., Charles Fergie, of Montreal, J. B. Tyrrell, Toronto, John A. Dresser, Ottawa, G. G. S. Lindsay, of Toronto, O. E. S. Whiteside, of Coleman, Alta. C. Blaylock, of Moyie, B. C., R. A. Bryce, of Cobalt, R. T. Hopper, of Montreal, and J. J. Penhale, of Sherbrooke."

The proceedings then terminated.

THE ANNUAL DINNER.

The Annual Dinner was held in the Ball Room of the King Edward Hotel, at 8 o'clock on Friday evening, covers being laid for one hundred and forty. Among the official guests of the Institute on this occasion were the Hon. Frank Cochrane, Minister of Mines of Ontario; Mr. F. T. Congdon, M. P., and Mr. Ralph Smith, M. P., representing the Yukon and Nanaimo district, B. C., respectively, in the Dominion Parliament; Dean Galbraith, of the University of Toronto, Prof. Richards, of Boston, Dr. James Douglas, Dr. Ledoux and Mr. B. B. Lawrence, of New York, and Dr. J. D. Irving, of New Haven, Conn.

The toast of "The King" having been duly honoured, that of "The Dominion and Provincial Governments" was proposed in a felicitous speech by Mr. G. G. S. Lindsey, K. C., and was responded to by the Hon. Frank Cochrane, Mr. Smith and Mr. Congdon.

Mr. COCHRANE in the course of his remarks said:

"I feel that I owe a great deal to this Institute. Its advice has been of great value to me. I consider it my duty to give due weight to the recommendations of the Institute, and so long as I occupy the office of Minister of Mines, I shall continue to keep in touch with the Institute and to do all that I can towards carrying out its suggestions in the interests of the mining industry of the Province. (Hear hear).

"The election of Dr. Miller to the presidency of this Institute afforded me, as it did also, I think, all the people of Ontario, the greatest possible gratification and pleasure. He is a man of whom we are all very proud. (Cheers). He has done a great deal for the mining industry of Ontario."

Mr. RALPH SMITH, M. P., replying on behalf of the Dominion Government, said:

"The Dominion Government some two or three years ago established a mining department under the direction of a responsible minister. They have also appointed a Select Committee of the House of Commons to conserve mining interests; and my good friend Mr. Congdon, the representative from the Yukon, and myself are proud to be members of that Select Committee, representing as we do, or as we think we do, the most important mining centres in the Dominion of Canada. (Applause).

"I believe, however, that there should be co-operation between the Dominion authorities and the Provincial authorities. (Hear, hear). Certain developments should be undertaken, and I believe that the interests of the community can only be properly served by complete and intelligent co-operation between the provinces, who have the constitutional powers, and the Dominion.

"I believe, too, that the Federal Department of Mines should extend its authority and influence over the mining enterprises of this country. I believe it is the business of that Department to be the distributor of the greatest possible amount of intelligence concerning mining industries and the mining values of this country. (Cheers).

"A few months ago we discussed the question in the Dominion Parliament of the necessity of the Dominion Government seeking to use its influence in favour of technical education in this country. As you know the supervision of the general education of the country is vested in the several provinces; but with regard to the technical education of the people, I believe it is the business of the Dominion Government to disseminate that intelligence. They have splendid scientific men in the Mining Department at Ottawa, and I believe that those men might well be employed in giving advice and instruction where it can advantageously be bestowed.

"You have discussed during this session of your Institute the question of accidents in mines in this country, and I submit that there is no more important question to be considered. You have questioned the statements of a certain gentleman with regard to the large percentage of mining fatalities in Ontario. Well, I have nothing to say as to whether or not those statements are correct; but I do believe that the death rate from coal mining accidents in British Columbia is the largest of any country in the world. To assist towards minimizing such accidents should be a function of

the Federal Department of Mines. The Marine Department at Ottawa has established schools for educating men in special lines. The Agricultural Department has created experimental farms, dairy schools, and has entered into a system for educating the agriculturist. This has proved very beneficial and I do not see, therefore, why the same principle should not be applied to mining. (Applause).

"I have stated that the percentage of accidents in coal mines in British Columbia during the last five years has been unduly high. That may possibly be accounted for by reason of the fact of the great development that is taking place and of the comparatively few educational institutions to prepare men for mining work or management. I am prepared to state that not a single cent is spent in British Columbia for the technical education of the miners of that country, and yet as a matter of fact—and my friend Mr. Lindsey, who is a practical mine manager himself, and who has been in that country for years, will bear me out—when we open these coal mines, we must perforce employ thousands of men who never were in a mine before, and you will agree with me that the lower percentage of accidents in mines in the older countries is due to the fact that the miners are trained men and understand the business from beginning to end.

"Therefore, it is the duty of the authorities to establish schools, to send scientific men into the mining district that the miners themselves may have an opportunity to gain information that will lead to their safety and security. You may talk about conserving the natural resources of the country; but let me say to you that the one thing that needs to be conserved in this country is the life of the labouring man (Cheers). Let the labouring men in the older country realize when they come to this country their lives are safe and secure, and you will have no difficulty in inducing good men, men who have had experience in mining in the older country, to come to Canada. So far as I am concerned, I am prepared to use my influence as a member of the Select Committee of the House of Commons in favour of increasing the efficiency of the Federal Department of Mines in this respect."

Mr. F. T. CONGDON, M. P., in replying to the toast spoke as follows:

"It seems to me it is a happy feature of the present state of affairs in Canada that we have passed beyond the initial period when there was constant friction between the Federal powers. The jurisdiction of each of the legislatures of this country has pretty well defined by the courts. There are numbers of matters with respect to which these legislatures must exercise co-ordinate power; but it is a happy augury of the present condition of Canada that we find the different legislatures, in which different political parties dominate, joining in their endeavour to work together in the common interest of the people of Canada; and I think with respect to the mining industry that one of the greatest things that could be attempted in Canada would be an endeavour by the Federal and Provincial Governments to pass a uniform Mining Act, applicable throughout the whole of Canada." (Cheers).

The toast of "The Mining Industries" was proposed by Mr. A. B. WILLMOTT and responded to by Mr. B. B. LAWRENCE and Mr. E. COSTE.

Other toasts were "Our Guests," proposed by Col. A. M. HAY, responded to by Prof. RICHARDS and Dr. IRVING; "Sister Societies," proposed by Dr. F. D. ADAMS and responded to by Dr. LEDOUX, representing the American Institute of Mining Engineers, and Dr. GALBRAITH, representing the Canadian Society of Civil Engineers; and "The Press" proposed by Col. HAY and responded to by Mr. FREDERICK HOBART, representing the *Engineering and Mining Journal*, of New York and Mr. J. C. MURRAY, the *Canadian Mining Journal*. The health of the retiring President, Dr. MILLER, was proposed by Mr. J. E. HARDMAN, while Mr. LAWRENCE proposed the health of the Secretary, and the Hon. Mr. COCHRANE the health of the ex-Treasurer, Mr. STEVENSON BROWN.

BRANCH MEETINGS.

WESTERN BRANCH—NELSON MEETING, SEPT. 25TH, 1909.*

Reported by E. JACOBS, Secretary.

The sixth general meeting of members of the Western Branch of the Canadian Mining Institute, was held in the rooms of the Nelson Board of Trade, Nelson, British Columbia, on Saturday, September 25, 1909.

Mr. Thomas Kiddie, chairman of the branch, presided, and there was a good attendance of members and others interested in the proceedings.

The first paper presented was that by Mr. T. Kiddie, entitled, "Causes of Variations in Ore Sampling." Messrs. W. F. Robertson, A. H. Gracey, A. C. Garde, M. J. Connelly, E. W. Widdowson, T. Kiddie and others took part in an interesting discussion which followed. At its close, a hearty vote of thanks was accorded Mr. Kiddie for having prepared a paper on such an important subject.

The secretary read a paper by Mr. W. D. L. Hardie on "The Galt Coal Field," and it was resolved that the secretary convey to Mr. Hardie, who is manager of the Galt collieries of the Alberta Railway and Irrigation Company, Lethbridge, Alta., the thanks of the meeting for his paper.

Several routine matters were disposed of, after which, the secretary reported that since the last meeting of the branch, one of its members, Andrew Colville, formerly superintendent of the Crow's Nest Pass Coal Company's Coal creek colliery, had died at Nanaimo, Vancouver Island.

Votes of thanks were passed to the Nelson Board of Trade for its courtesy in placing its rooms at the disposal of the branch for its meeting, and to the secretary, for his services throughout the year in the interests of the branch, and an adjournment to Spo-

* For full report see Bulletin C.M.I., No. 8, 1909, p. 4, et seq.

kane, Wash., to there hold, on Wednesday morning next, a joint meeting with the American Institute of Mining Engineers was made.

VANCOUVER MEETING, FEB. 26TH, 1910. VANCOUVER, B.C.*

Reported by E. JACOBS, Secretary.

The Seventh General Meeting of the Western Branch of the Canadian Mining Institute was held in Vancouver, B.C., on Friday, February 25.

MORNING SESSION.

The morning session was held in the Hotel Vancouver. After the chairman of the branch, Mr. Thomas Kiddie, had called the meeting to order, Mr. Ewing Buchan, on behalf of the Mayor, who had been prevented by other engagements from being present, delivered an address of welcome.

Mr. Campbell Sweeny, as a representative of the banking interests in Vancouver, also addressed the meeting.

THE CHAIRMAN:—Mr. Sweeny has directed attention to the lack of cash capital in connection with the development of some of our mining properties. I have in mind an illustration of those early days which I cannot help mentioning at this time, because it will serve to show how former methods tended to depreciate the estimation of a really valuable mine. That property is situated in this Coast district, and the company owning it was capitalized at $5,000,000. What little money was expended on the property resulted in the sinking of a shaft to a depth of 120 feet and the making of a few holes in the ground. Then the affairs of the company became involved, going from bad to worse until eventually it had to cease mining operations. Comparatively recently the property was taken over by a Vancouver syndicate with $50,000 capital, of which, I have been informed, but $20,000 has been called up. Last week I had the pleasure of seeing the balance sheet showing last year's transactions, and I ascertained that as a result of operations the syndicate made a profit for the year of $52,000, and this,

* Abstract. For full report see Bulletin, C.M.I., No. 10, 1909, p. 65 et seq.

too, after paying the old company royalty to the amount of $26,000. I mention this as a striking instance of where a lack of cash capital in the beginning was to a large extent the cause of a suspension of mining operations by the company owning what, under more favourable financial conditions, has since been proved a valuable ore-producing and profit-earning mine.

CHAIRMAN'S ADDRESS.

The Chairman then addressed the meeting as follows:—

"GENTLEMEN:—The total value of the mineral production of the Coast district during ten years, 1900-1909, is rather more than $50,000,000. While this sum represents only about one-fourth of the value of the mineral production of the whole of British Columbia during the period just mentioned, it is a large amount, for it shows an average yearly value for this ten-year period slightly in excess of $5,000,000. Now, when it is remembered that the value of the mineral production of the Coast district in 1909 was approximately $6,200,000, which is the highest total for any year to date, it will at once be recognized that the mining industry in this district is indeed an important one, the more so since the value of its mineral production is increasing as the years pass. If there were no other reason for holding to-day, here in this city of Vancouver—the largest and most progressive city on the Pacific Coast of Canada—a meeting of the Western Branch of the Canadian Mining Institute, this is, I have no doubt you will agree with me, of itself an amply sufficient reason for this gathering.

"There is not time at my disposal this morning to allow of my adequately reviewing the mining industry of this Province, but I may be permitted to present to you a brief survey of its recent progress and present position, as indicated by the following facts concerning the several branches of this important industry.

"*Gold.*—While the production of placer gold has not shown any substantial increase in recent years, there are features to-day which warrant the expectation that there will in the near future be a considerable improvement. I need only make passing reference to the fact that in the Cariboo district there are two or three hydraulic mining enterprises on a comparatively large scale, either already established or being prepared for, to show that we may expect in the future a larger production of placer gold than in recent years.

"The position in Atlin district has been shown in an excellent paper by Mrs. R. Watson Young, recently published by the Canadian Mining Institute. Here, too, there is good reason to look for an increase in production as operations shall be enlarged.

"Lode gold mining gives promise of yielding larger total returns, both from stamp milling operations in Hedley Camp, in Similkameen district, and in Sheep Creek Camp, in Nelson District. The considerable increase in the smelting of copper ores also containing gold will add to the production of the latter metal.

"*Silver.*—The production of silver is greater now than it was a year or two ago. Operations in the Slocan District, including Ainsworth mining division, are being extended, and the quantity of silver extracted from the ores mined in that district added to. In this connection, it is noteworthy that the Consolidated Mining and Smelting Company of Canada, Ltd., is producing comparatively large quantities of refined silver, as well as gold, at its works at Trail, West Kootenay, and is selling part of its product to the Ottawa Branch of the Royal Mint, for use in coining Canadian money.

"*Lead.*—The beneficial effect of the bounty paid by the Dominion Government on lead mined in Canada is seen in the continued operation of numbers of silver-lead and lead mines in both East and West Kootenay districts. At Trail, where is situated the only operating lead smelting and refining works in Western Canada, many improvements and enlargements have recently been made, these providing for the smelting of a larger tonnage of lead ores. In the increase in size of the lead blast furnaces, installation of more Huntington-Heberlein roasters and converting pots, and in the considerable extension of the electrolytic lead refinery, are evidences of substantial progress.

"*Copper.*—The mining of copper ores on a large scale is being continued, notably in the Boundary District, where about 6,000 tons of ore a day are being mined, and the greater part of this large tonnage smelted at district smelting works. The important improvements lately completed at the Granby Company's smeltery, bringing its total treatment capacity up to about 4,500 tons of ore a day, and its copper converting capacity to about 36,000,000 pounds of copper per annum, is indicative of the advance being

made in this branch of mining. The smelting works of the British Columbia Copper Company, too, are quite modern and of large capacity, while at Trail the Consolidated Mining and Smelting Company has built the largest copper blast furnaces in Canada, and is also enlarging its copper smelting operations. On the Coast important improvements have been made at the works of the Tyee Copper Company, at Ladysmith, where there has been installed a second blast furnace of larger capacity than that previously in use at those works, and other additions to plant have been made to provide for the steady increase in copper smelting this company's enterprise is bringing about.

"*Iron.*—During the year last past considerable attention has been paid to iron mining and smelting on the Coast. One of the largest iron properties in this district has recently been sold to United States capitalists. While the plans of these men have not been made public, it is reasonable to assume that it is their intention to ere long proceed with the mining of iron ore and the manufacture of pig iron; and possibly steel also.

"Another enterprise is that of the Western Steel Corporation, organized last year to operate the iron manufacturing plant at Irondale, Washington. It is the intention of this company to erect in British Columbia a modern iron smelting and steel manufacturing plant; and in this connection they have already secured valuable coal-bearing lands and magnesite property at Atlin. When this enterprise shall have been developed it will tend to the upbuilding in the Province of another important industry, and that at no distant date. In due time, as a market shall be found for their products, allied industries, such as carworks, nail manufactory, etc., will be added.

"*Zinc.*—The solution of the problem of a profitable method of treatment of the low-grade lead-zinc ores of British Columbia, particularly of the Slocan district, is a matter of much importance. The Provincial Government has already aided considerably in a financial way experiments towards solving this problem, and it is earnestly hoped the Dominion Government will soon take steps to continue this experimental work, as it has been requested to do by many of those deeply interested in this question.

"The solution of this problem of developing a cheap and effective method for the treatment of low-grade lead-zinc ores of the

Province is of much moment to the mining industry. Whether this be done by electro-thermic process or otherwise is of secondary importance, the vital point being the determination of how best to treat these ores at a profit to mine owners. An example of existing difficulties may be given as follows:—Last year a shipment was made of ore containing 30 per cent. zinc and 30 ounces of silver per ton; the net return to the shipper from the smelter was only $3 per ton, which was considerably less than it had cost to mine the ore, so that the transaction was a loss.

"*Coal and Coke.*—There has been much expansion in this branch of mining. In addition to a large output having been made from the older collieries of the Province, several new collieries are now producing, so that their output will add materially to the total production of coal. A pleasing feature is that these new enterprises are finding new markets for their products, so that their establishment is a decided advantage to the industry and the Province."

"*General.*—The foregoing notes but skim the surface of the position to-day as regards the mining industry of British Columbia. In conclusion, it may be said with confidence that there is much promise of greater progress in the near future and that mining will become more profitable than it has been in the past in this Province."

After concluding his address, the Chairman stated that an application had been made to the Provincial Government for a grant of $1,200 per annum to enable the branch to better carry on its work. No reply had yet been received, but it was understood the matter had been favourably considered by the Government.

MR. W. F. ROBERTSON:—Yes; the estimates presented to the Legislative Assembly yesterday include an item of $1,000 for the purpose mentioned by the Chairman. (Applause).

Messrs. W. M. Brewer and H. H. Claudet having been appointed scrutineers to examine and count the ballots received in connection with the election of Chairman of the Branch for the ensuing year, the meeting was adjourned until two o'clock in the afternoon, at the rooms of the Vancouver Board of Trade.

AFTERNOON MEETING.

In the afternoon the meeting was called to order shortly after two o'clock.

Secretary's Report.—The Secretary read his report for the year 1909. This gave much information relative to the membership of the Branch; number of meetings held during the year, together with a synopsis of the proceedings thereat; and other particulars concerning the work and progress of the Branch in the West, especially in British Columbia. The following is a summary of the report:—

Membership:—At the close of 1908 the total number on the Branch membership roll was 189, this including full, associate, and student members, all resident in Western Canada or the adjoining State of Washington. The losses during the year by removals, resignations, etc., totalled 24, while there were elected 23 full members and 6 associate members, and to these were added 7 accessions by arrival of members from other parts to reside in Western Branch territory, making a total of 36 or a net gain of 12, which brought the membership total to 201 at the close of 1909. At the time the meeting was being held there were 10 applications for membership from residents in the West, so that, if elected, these would be in due course added to the Branch membership roll. Among the losses was that of the late Mr. Andrew Colville, who died at Nanaimo on July 15, 1909.

An analysis showing the distribution of members, as regards place of residence, indicated that 153 reside in British Columbia, 35 in Alberta, 1 in Saskatchewan, and 12 in the State of Washington, U.S.A.

Branch Meetings:—There were three general meetings held in 1909. On January 25-26, at Greenwood, with Mr. S. S. Fowler in the chair. The attendance at this meeting consisted of 16 members, four applicants for membership (afterwards elected), and a number of locally resident non-members.

At Coleman, Alberta, a formal meeting was held on May 25th, with Mr. W. A. Davidson in the chair. The attendance was small, owing to the fact that nearly all the members resident in the district were on that day at Macleod, at a meeting of a Board of

Conciliation and Investigation in connection with a general strike of coal miners in the district. Two applications for membership were received at Coleman, and the Branch Secretary afterwards obtained six others, all from men interested in coal mining in Southern Alberta.

The meeting at Nelson on September 25th was attended by 14 members and six non-members.

Finances.—The expenditures during the year were shown to have totalled about $576, of which $300 was allowance to the Branch Secretary, and the remainder for his travelling expenses, printing and stationery, and payment made to stenographers for reports of meetings.

Papers by Western Members.—A list of these was given in the report. The Secretary's comment was:—"While a fair proportion of these was submitted to branch meetings, others were not. The members and visitors who attended the branch meetings are under obligation to those who co-operated in making the meetings successful by contributing papers for reading and discussion at those periodical gatherings."

General.—"In closing this review of the year 1909 the Branch Secretary ventures to urge all members to take an active personal interest in the extension of the work of the Branch and generally in increasing substantially the influence and strength of the Canadian Mining Institute, which includes within its membership a large majority of the leading geologists, mining engineers, metallurgists, and others intimately associated with the development of the great mineral resources of the Dominion. The potentialities of Western Canada in regard to both metal and coal mining are large to a degree not easily realized, and development and utilization of the immense mineral resources of the West are comparatively slow; yet since the mining industry of this part of the Dominion gives direct employment to 14,000 or 15,000 men, it should be regarded as a reasonable ambition for members of the Western Branch of the Institute to see the membership of the Branch at least doubled and the parent Institute strengthened thereby. 'A long pull, a strong pull, and a pull altogether,' would be an excellent maxim for western members to make their own. May a large majority of them decide to do so, and bestir themselves accordingly."

ELECTION OF BRANCH CHAIRMAN.

The scrutineers reported that of the 67 ballots cast, 65 were for Mr. W. F. Robertson, and one was spoiled. The Chairman congratulated Mr. Robertson on his practically unanimous election as Chairman of the Branch for the ensuing year, and the members on having secured so desirable a chairman. He had known Mr. Robertson many years, both in business and private life, and he had pleasure in assuring the meeting that he did not know anyone he considered better qualified to fill the position to which he had been elected. Under Mr. Robertson's chairmanship the affairs of the Branch would be in safe keeping.

Mr. Robertson expressed his thanks for having been almost unanimously elected chairman, and stated that he would carry out the duties of that office to the best of his ability.

Votes of thanks were passed to the retiring chairman (Mr. Kiddie) and the Branch Secretary (Mr. Jacobs) for their respective services during the past year. A vote of thanks to the Provincial Government for having made a money grant to the branch, was also passed, and Mr. Kiddie was deputed to wait upon the Hon. the Premier (Hon. Richard McBride) and personally thank him for this assistance. The necessity or otherwise of appointing a treasurer for the branch was left for the branch council to decide.

On the suggestion of the Secretary it was decided that the next general meeting of the Branch shall be held in May, at Grand Forks, Boundary district.

A discussion took place on the question of endeavouring to secure the establishment of telegraphic communication with Stewart, at the head of Portland canal. Messrs. A. G. Langley, who introduced the subject, E. Cave-Brown-Cave, and W. M. Brewer each gave the meeting information, after which it was decided that the Secretary should telegraph to the Hon. Wm. Templeman, asking him to take up with the Dominion Government the matter of giving Stewart direct connection with the main telegraph line to Yukon Territory; also that the co-operation of the Boards of Trade of Vancouver and Victoria should be sought. Mr. Buchan assured the meeting the Vancouver Board of Trade would interest itself in this matter, and Mr. Trewartha-James undertook to bring it before the Victoria Board of Trade.

On motion of Mr. Langley, seconded by Mr. Trewartha-James, it was decided to request the Provincial Government to establish a survey line and bench marks in the Portland Canal district. Mr. Langley explained that many claim holders wanted to be sure the boundaries of their claims were correctly set out, but as one land surveyor's word was as good as another's, there could not be any certainty on the point until after a triangulation survey had been made and a base line established. A few bench marks, giving the elevations at various points, would also be of great service. Mr. J. L. Parker stated there was a general survey point established beyond the camp of Mr. C. H. Dickie, manager of the Portland Canal Mining and Development Company.

On motion of Mr. Trewartha-James, seconded by Mr. Brewer, it was resolved that the Dominion Government be requested, through Hon. Wm. Templeman, Minister of Mines, to remove any existing custom duties on oxygen breathing apparatus for life-saving in coal mines; that in the opinion of this Branch all such apparatus as shall be installed by companies operating in British Columbia should be of a character as nearly uniform as shall be practicable with that in use in the United States; and that the Branch Secretary write to Dr. Holmes, of the United States Geological Survey, for information as to what had been done by the Survey in connection with providing such apparatus in the United States. Those taking part in the discussion preliminary to passing this resolution were Messrs. Trewartha-James, W. F. Robertson, S. J. Castleman, W. M. Brewer, and R. G. Drinnan.

READING AND DISCUSSION OF PAPERS.

Mr. Trewartha-James resumed discussion of Mr. Kiddie's paper on "Causes of Variations in Ore Smelting," read and discussed at the meeting held at Nelson last September. Following a somewhat lengthy comment by Mr. Trewartha-James, Messrs. H. H. Claudet, W. F. Robertson, J. L. Parker, and T. Kiddie, each contributed to the discussion, an account of which will appear in the Bulletin separately.

A paper on "The Classification of Nicola Valley Coals" was read by Mr. S. J. Castleman. Messrs. Robertson, Parker, Barclay Bonthrone, Trewartha-James and the Chairman took part in the discussion of the subject of this paper.

The last paper submitted was one by Mr. Kiddie on "Notes on Metal Losses in Copper Slags." Mr. Kiddie having, in concluding his paper, paid a tribute to Messrs. Parke Channing and Wright who, he said "originally figured back on the discrepancy of gold to copper," Mr. Robertson observed: "We have all read between the lines; Mr. Kiddie is a little too modest. The men he has mentioned are in the very highest class of metallurgists in the United States. But while they suspected a thing, and were looking for it, it had been an every-day practice in Mr. Kiddie's smelting operations, which shows distinctly that in this matter he has been in advance of them."

GRAND FORKS MEETING, MAY 26, 1910.

The eighth general meeting of the members of the Western Branch was held at Grand Forks on May 26th.

The chairman announced the re-appointment of Mr. E. Jacobs to the secretaryship of the branch.

The result of the ballot for Branch Council for the current year was also announced as follows:—Messrs. W. H. Armstrong, Vancouver; S. S. Fowler, Riondel; Norman Fraser, Michel; Charles Graham, Princeton; Thomas Graham, Nanaimo; J. C. Haas, Spokane, Wash., U.S.A.; John Hopp, Barkerville; W. H. Trewartha-James, Victoria; A. G. Larson, Rossland; F. Chas. Merry, Ferguson; Lewis Stockett, Bankhead, Alta.; and W. E. Zwicky, Kaslo.

The secretary reported that in consequence of the resolutions adopted at the Vancouver meeting of the branch, urging the Dominion Government to provide telegraphic facilities by extending the systems to Stewart in the Portland canal district, Parliament had voted an appropriation in the supplementary estimates for this purpose. Before proceeding, however, to extend the present system, the government was undertaking experiments with the wireless system in order to ascertain whether that would meet the requirements of the district. A vote of thanks to the Dominion Government for its prompt response to the recommendation made by the branch, was adopted.

The chairman stated that he understood some correspondence had passed between the Dominion and Provincial Govern-

ments relative to the exemption from payment of customs duties on oxygen breathing apparatus for use in mine rescue work, and that arrangements would be made for the free entry of such apparatus. The chairman also described to the meeting the mine rescue training work now being carried on by the Technological Branch of the U.S. Geological Survey at Seattle, Wash., and mentioned that a request from a Vancouver Island coal mine for assistance in a recent case of emergency, had met with a ready response from this station.

Papers were read on "The Geology of the Phœnix Ore Deposit," by M. O. E. LeRoy; on the "Silver and Gold Deposits of the West Fork of Kettle River," presented by Mr. L. Reinecke and on the "Mineral Resources of a part of Yale District," by Mr. Chas. Camsell.

Cobalt Branch.

A meeting of the Cobalt Branch was held in the Board Room of the Mine Managers' Association Building in Cobalt, on Thursday, November 25th; some thirty members and others were present.

In the absence of Mr. R. W. Brigstocke, Mr. T. R. Jones was voted to the chair. Subsequently the Secretary announced that as Mr. Brigstocke would in future spend very little of his time in Cobalt, that gentleman desired to resign the Chairmanship of the Branch, and on motion of Mr. MacDonald, Mr. Jones was elected to this office for the ensuing year.

Mr. H. Mortimer-Lamb, Secretary of the Institute, then read a paper entitled, "Some notes on the History and Recent Developments of the Canadian Mining Institute," which was productive of an interesting discussion on the present system of classification of candidates for admission to the Institute. This discussion culminated in the unanimous adoption of the following resolution:—

"Resolved—that the Cobalt Branch place itself on record as expressing the opinion that the present system for the classification of applicants for enrolment as members is unsatisfactory, inasmuch as the requirements for membership are not sufficiently stringent, and the Branch, therefore, suggests that a Committee be appointed by the Council to consider the desirability of establishing a certain standard classification for active membership."

As supplementary to some of the points raised in his paper, Mr. Lamb also read a very interesting paper contributed by Mr. J. D. Kendall, of London, Eng., on the subject of "Mining Engineers and Mining Institutes." This paper will also be presented and discussed at the Annual Meeting of the Institute in March, 1910.

Mr. Arthur A. Cole then delivered a few remarks explaining the methods adopted in making his relief map of the Cobalt area, a specimen of which was exhibited to the members present. The construction of this map occupied the time of Mr. Cole and an assistant for nearly six months, and is a very complete and beautiful model.

MONTREAL BRANCH.

A meeting of the Montreal Branch of the Institute was held in the Windsor Hotel, on Tuesday, December 21st, 1910, for the purpose of electing officers for the ensuing year. Mr. Chas. Fergie occupied the Chair. On motion of Dr. J. Bonsall Porter, seconded by Mr. R. T. Hopper, Mr. John E. Hardman was elected Chairman of the Branch, and Mr. E. Dulieux, Professor of Mining Engineering, Ecole Polytechnique, Montreal, was elected to the office of Vice-Chairman. On motion of Mr. H. Mortimer-Lamb, seconded by Dr. A. Stansfield, Dr. A. E. Barlow was elected to the office of Branch Secretary.

SHERBROOKE BRANCH.

A meeting was held at Sherbrooke on Friday, May 27th, with a view to the resuscitation of this, the oldest established Branch of the Institute. With this object in view, some sixty members and others assembled in the Madoc Hotel on the evening in question, in response to the invitation issued by Mr. J. J. Penhale. Among those present were the President of the Institute, Dr. F. D. Adams; Dr. A. E. Barlow, Vice-President; Mr. J. A. Dresser; Mr. J. C. Gwillim; Mr. C. Camsell; Mr. T. Denis, Provincial Superintendent of Mines, and the Secretary of the Institute, while several mining sections of the Eastern Townships, including Thetford, Black Lake, Coleraine, Danville, Eustis and

Capleton, were well represented. After brief addresses by the President and others, Mr. J. J. Penhale, of Sherbrooke, was elected Chairman of the Branch, and Mr. W. H. Smith, of Thetford Mines, Secretary for the ensuing year. The Chairman stated that one of the chief objects of the gathering was to afford the mining men of the Eastern Townships an opportunity of meeting Mr. T. Denis, who had recently been appointed to the office of Provincial Superintendent of Mines. In this connection he referred to Mr. Denis' high professional attainments, and observed that the Province was extremely fortunate in securing the services of a gentleman of M'. Denis' ability and industry. Before the meeting closed, twenty-two applications for membership in the Institute were handed to the Chairman, to be dealt with by the Council of the Institute.

Kingston, Ontario Branch.

Reported by E. H. Birkett, Ass't Secretary.

A meeting of this Branch was held at the School of Mining, Kingston, on April 30th. The President, Prof. J. C. Gwillim, occupied the chair. The Secretary presented a report showing the student membership for the year to number forty-two. The President summarized the advantages of membership in the Canadian Mining Institute, and strongly advised student members to apply for full membership after they had completed their University course.

The election of officers for the ensuing year resulted as follows:—

President.....Prof. M. B. Baker.
Vice-President.....W. M. Goodwin.
Secretary.....John Donnelly.
Ass't Secretary.....W. H. Hutchison.

McGill Mining Society.

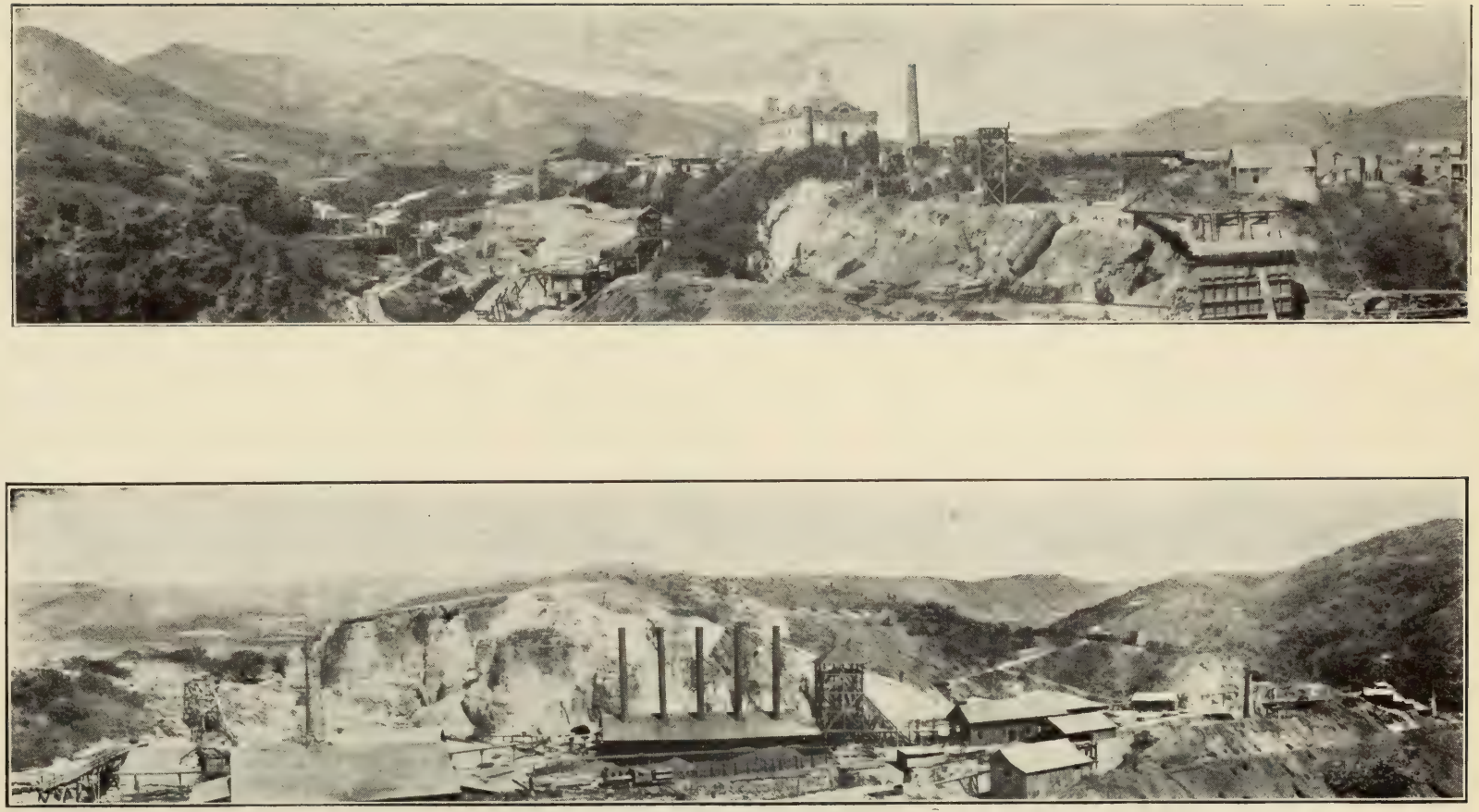
Two meetings of this Society have been held since the beginning of the year; one on January 28th, when an address on the "Ethics of Mining Engineering" was delivered by Mr. J. C. Murray,

Editor of the *Canadian Mining Journal;* and the second, on February 12th, on which occasion a very interesting address was delivered by Dr. Adam Short, Chairman of the Civil Service Commission, on the subject of "The Relation Between Capital and Labour, with Special Reference to Strikes."

At the annual meeting of this society, the following officers were elected: —

Hon. President . . . . . Dr. J. Bonsall Porter.
President . . . . . G. A. Porter (Sc. 1911).
Vice-President . . . . . G. E. Murray (Sc. 1911).
Secretary-Treasurer . . . . . W. R. Flewin (Sc. 1911).

PAPERS



General View of El Cobre.

"TWO CUBAN MINES."

By BENJAMIN B. LAWRENCE, New York.

(Annual Meeting, Toronto, 1910.)

EL COBRE.

It may surprise many to learn that the first copper mined in quantity by civilized man on the Western Hemisphere, came from the El Cobre Copper Mines, at Santiago de Cuba; and much information of historical interest relative to this property may be found in the government archives at Santiago.

It seems that the first discovery of copper was made by Spanish adventurers in 1544, nine years after the founding of the town now called "Cobre." The mine lies twelve miles northwest of Santiago Bay in the valley of Rio del Cobre, in the Sierra Mæstre Mountains, 400 feet above sea level.

In the early days, this town lay in the centre of rich coffee and sugar plantations, and the mountains in which the El Cobre Mine is situated was the summer resort, as it were, of merchants residing in Santiago.

In these days El Cobre was by far the most important town in Oriente Province. From the time of its discovery the mine attracted wide attention in Spain, and the Crown was richer by vast sums from its operations, the Queen of Spain herself being personally interested in the railway which was subsequently built to bring the ore to the coast. The property was worked for a century by the Spaniards, who employed for the purpose slaves, both African and Chinese.

The most important feature of El Cobre and one that has made it widely known throughout the world, is the Sanctuary of the Virgin of Cobre. This stands upon the very apex of the

Cobre Vein, and its pink dome and square blue towers may be seen from any point in the mountains for miles around. I submit photographs of this interesting building. The incident of its erection forms a part of the history of the mine itself.

Alonzo Ojeda, from San Domingo, wrecked upon the shores of Cuba early in the 15th Century, was saved from death by an Indian Chief, Cacique by name. Ojeda had with him an image of the Virgin, and, in fulfilment of a vow conditional on the saving of his life, built a chapel to her in the town of Cuieba. This was the first Christian Chapel in the Island of Cuba. The Indian Chief, however, stole the image to try the Lady's charm against his enemies, and it is said that so great was her power that he never lost a battle while he had the image in his possession.

In 1600, so legend has it, Juan de Joyos and Rodrigo de Joyos, Indians, and Juan Moreno, a negro, found the image floating in the Bay. On a board upon the image was written—"Yo soy la Virgin de la Caridad"—"I am Our Lady of Charity." These three men took the image to Hato, where the Mayor erected an altar for her, at the same time notifying the manager of the Royal Mines at El Cobre, Don Francisco Sanchez de Moya, that he had done so. Francisco built a chapel for the Virgin, first at Hato, and afterwards she was brought to Cobre, and a chapel was built for her in the town.

As the mine prospered, Our Lady of Caridad became, as it were, the Patron Saint of the mine, and the Sanctuary was built for her protection on the present site. It is a handsome building, 150 feet x 90 feet, supported by massive columns, and is reached by 430 steps from the village below. Up these steps on their knees the pilgrims passed in thousands to pay their "promesas" to the Mother of Charity, and many wonderful cures of the sick are mentioned. Back of the chancel is a pile of crutches and canes, testifying to the fact that cripples had left the Sanctuary without these aids to locomotion.

Heroic figures of the Saints stand on either side of the entrance to guard the Virgin, who, in her cloth of gold, stands on the altar under the great dome. The figure is about the size of a child's doll, and holds a small image of the Holy Infant in her left hand, who in turn holds a sphere symbolizing the world. The Virgin's right hand is raised in benediction.

1. The Sanctuary from the Town.
2. The Town of El Cobre.
3. Smelter and Concentrator at Punta Sal.
4. The Sanctuary with Modern Head Frames among the Ruins.

To-day Our Lady of Caridad reigns disconsolately in the old station of the Cobre railway, at the foot of the old steps. The Sanctuary, however, still stands as a monument to days gone by.

In 1700, Francisco Sanchez de Moya was succeeded at the mines by Juan de Equilus, who obtained a concession from the Spanish Crown, agreeing to pay 200 tons of copper yearly to the Arsenal in Havana. Failing to pay his tribute, he was put in jail, and his successor fared no better. The mines were then worked by the Crown until 1830.

As early as 1623 the English displayed much interest in the yield of copper Spain enjoyed from the Island of Cuba, and had already cast somewhat longing eyes in this direction. It is recorded that Oliver Cromwell sent a Commission to Cuba to investigate this deposit; but there is no record concerning the report of such a Commission.

The first appearance of the English on the scene was in 1830, when the "Consolidated Company," an English Syndicate, purchased some of the claims from the Crown of Spain, and mined actively until the necessary suspension of operations occasioned by the ten years war in 1869. Meanwhile this period of thirty-nine years of operation seems to have been the most active in the history of the mine. Tall chimneys of rounded stone rise from among the rusted shells of old Cornish boilers, and the great low pressure cylinders of the Cornish pumps are still on the ground, testifying to the energy which characterizes the English race. Even block houses were built to defend the operators from attack. There is still on the ground a cast iron pump-bob weighing 60 tons, made in Glasgow, which it is alleged occupied the energies of 500 men for six months to transport it from the coast to the mine.

Forty old shafts are recorded, and remnants of old hoisting machinery litter the ground. One flat woven wire rope, 6 inches wide and one thousand feet long still remains upon the reel.

Many of the buildings were of massive stone, and provided with port holes indicating that they were used not only for dwellings, but for defence purposes in cases of attack.

On the topmost point of one of the highest hills, known as Hardy Hill, are the remains of the former manager's house, to

which a zig-zag trail leads. At this height a magnificent panorama presents itself of Santiago Bay, the entrance guarded by Morro Castle and beyond the sweep of ocean. From this height the stirring events of the Fourth of July, 1898, could have been watched, when Cevera's fleet was defeated and captured just outside Santiago Bay.

The underground labour during English operations was performed by black slaves and Chinese, supervised by Cornish mine captains. Much in the records with reference to the operations at this time is tragic in the extreme, for the mine managers had under their command a corps of armed men, and the treatment of the slaves is said to have been cruel. Slaves were paid $15 per month, and an old letter from one mine manager mentions that more Chinese labour must be introduced since slaves were scarce and free labour commanded the prohibitive wage of $24 per month. Such a wage now-a-days would certainly not appear excessive.

Rock and ore were hoisted in buckets and stull-timbering was exclusively used. Much ore was in consequence left in the mine, since no method was devised for mining the ore under conditions when the ore body bulged.

When the mine was pumped out, many handsome mahogany stulls of large size were found, and these beautiful stulls 24″ x 24″, 30 to 40 feet in length, were again used in retimbering dangerous places. A wooden pump rod 18″ x 20″, and 63 feet long, was removed from the shaft. These timbers were perfectly preserved by the copper sulphate waters, and, as already remarked, were used again after an interval of fifty years.

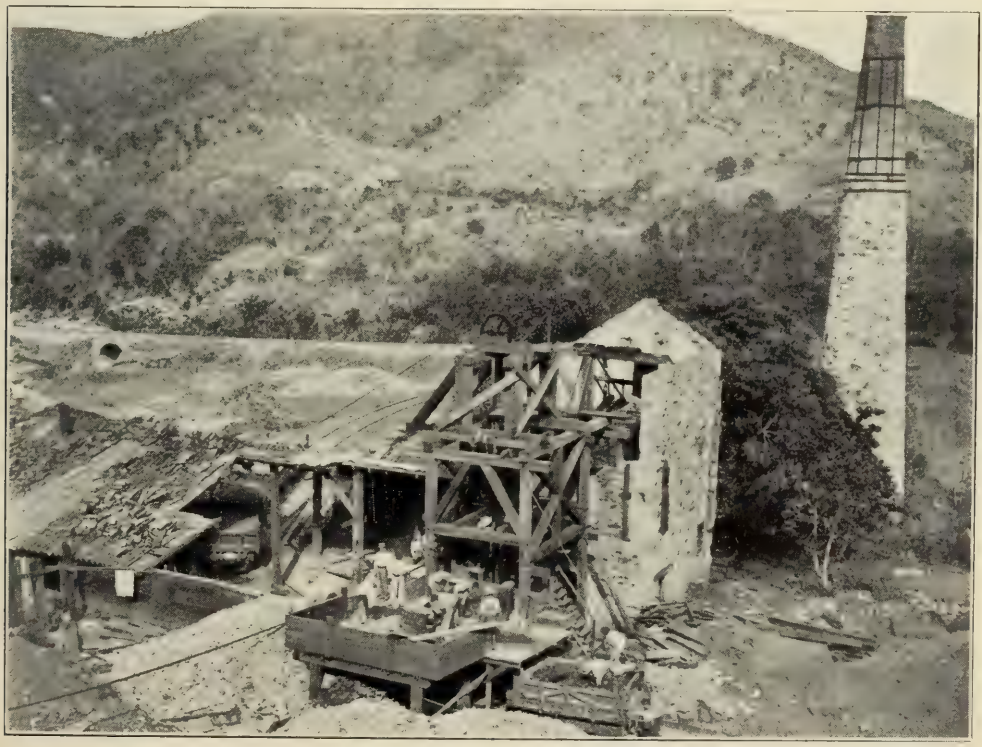
In 1869 as the mines became deeper greater difficulty was experienced in keeping the workings dry, especially in the rainy season. The breaking of the Cornish pumps caused serious delays, out of which lawsuits arose between the Spanish and English Companies operating the mines. A very complete history of this litigation is given by one Quintana, a mine inspector employed by the Spanish Government.

As shown in the accompanying photographs, much of the surface of the property is covered by fine tailing dumps, the result of hand-jigging. There are also the remains of an old stamp mill—all of which is proof that much of the ore was concentrated before

Old Cornish Pump —El Cobre Mine.

Old Dumps.

Old Stack at El Cobre—The Sanctuary may be seen in the Middle Distance.



A Modern Head Frame in an old Shaft House.

shipping. And indeed the concentration of this ore was necessary as the freight rate to the coast and to England was excessively high.

Previous to the year 1844, when the railroad was built, the ore was "packed" to the coast on mules, and camels were also for a time employed, but in such a rocky country proved to be of little use.

In 1844 the Cobre Railway, eight miles in length, and replacing the use of 2,000 mules, was built. The Queen of Spain was the principal stockholder in this railway, and a freight rate of $6.00 per ton for down and $4.50 for up freight, was established. The railway was built, as our manager, Mr. Emerson, says, "with a fear of curves and a disregard of grades, which necessitated five important bridges and one incline, up which the trains were hoisted by cable!" The railway became, from its commanding position, the controlling feature of the property, and ultimately such high freight rates were charged as to leave no margin of profit to encourage the re-opening of the mine at the conclusion of the ten years' war. For example, no ore carrying less than 13 per cent. copper could be shipped with profit.

In these days the ore was sent to Swansea, Wales, and was treated in reverberating furnaces.

The old companies had the advantage of a high price for copper and cheap labour, but were handicapped by inadequate pumping machinery, inferior methods of mining, and high freight and treatment charges. In 1869-70 all operations were suspended, chiefly by reason of the war which centered around Santiago. Some thirty years later, in 1901, after the conclusion of the war with Spain, a New York syndicate was organized for the purpose of unwatering the mines.

In order to install modern machinery in the mines it was first necessary to rebuild the railroad. As it had been entirely destroyed, this was no light undertaking. The mine was equipped with heavy pumps, and the first difficulty encountered was occasioned by the copper in the water, which had a disastrous effect on the pipes and pumps. Again, the shafts proved to be full of miscellaneous debris—old pump rods, timber, boxes of cartridges, cannon balls and human bones were removed. These difficulties delayed the unwatering for more than two years; and when,

finally, a depth of some 200 feet was reached, the company had the misfortune to experience an exceptionally rainy season accompanied by unprecedented floods, which latter carried away a large part of the town of Cobre and five railway bridges, while some 35 people were drowned.

The following year, 1903, the 500 foot level was reached, and some mining was commenced in the unwatered area. The railway was repaired, and a 250 ton smelter and 400 ton concentrator built at Punta Sal, the port. The company smelted and concentrated some 85,000 tons of ore averaging 7% copper in this year. The water taken from the mine for the first six or eight months contained some 400 grams of copper per cubic meter. This water was run over Californias, as is the practice to-day. After the first year, however, the copper contents in the water rapidly decreased, and now only about 50 grams of copper per cubic meter is recovered.

The large quantity of low grade oxide ore in and about the surface workings led to the erection of a leaching plant using sulphuric acid; but owing to the loss of acid and heavy cost of transportation, this undertaking was as unprofitable.

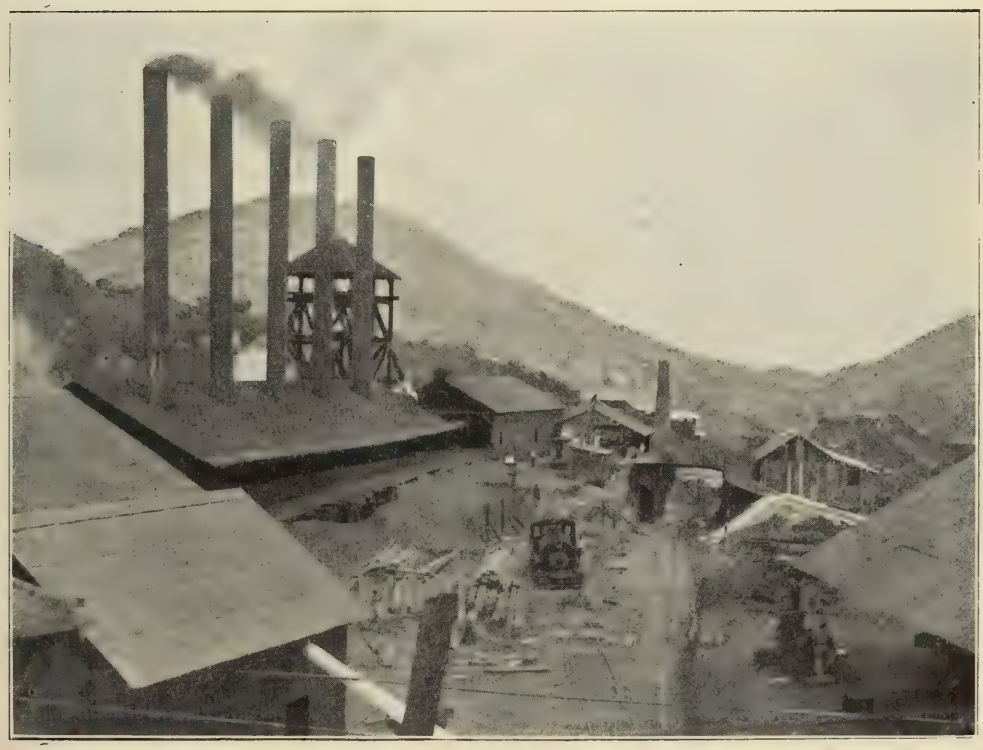
As greater depth was obtained the old workings were found to be badly in need of timbering. They were, moreover, filled with a soft mud, and it proved a most dangerous and expensive task to lower to the 800 feet. Bad air from rotting timber and sulphides caused much annoyance, and some deaths, and caves of old stopes were a constant menace.

In spite of all these difficulties, work was continued at enormous cost, and a considerable production was being maintained when in May, 1906, a cave-in occurred which for a time practically rendered the lower portions of the mine inaccessible. At the time of this disaster 60 miners were confined in stopes filled with bad air; but through the heroic work of the Superintendent, M. B. Yung, and his assistant, who is now superintendent of the mine, Edward B. Nagle, only two men lost their lives.

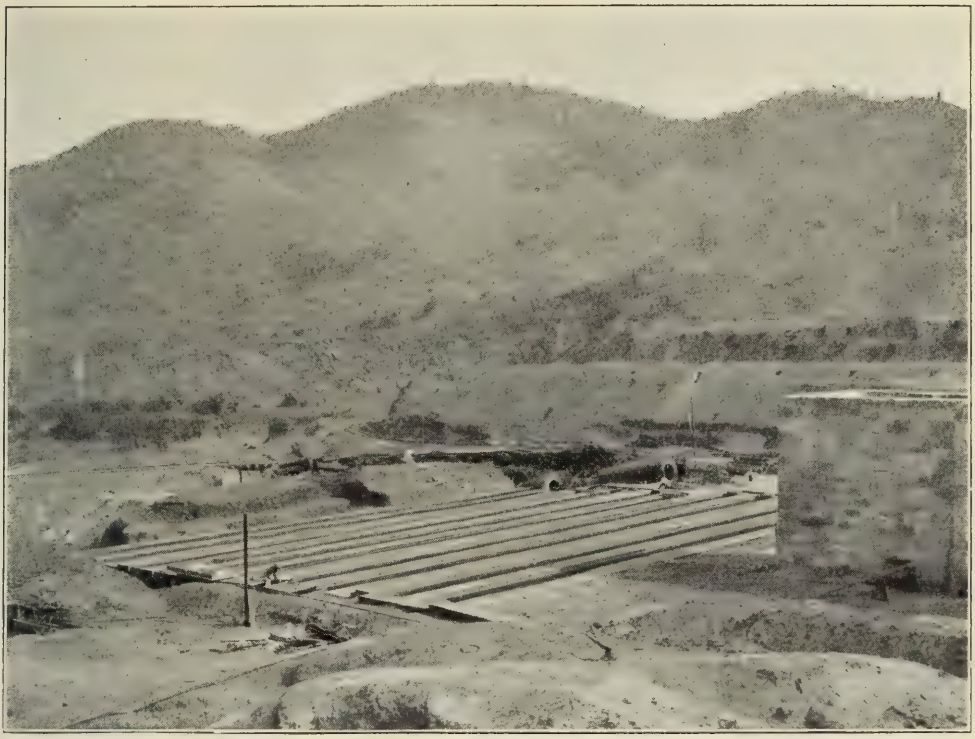
The pumps were pulled and the old mine temporarily abandoned. This was in 1906.

The management of the Company now gave attention to working the upper portion of the property and to the outlying, or adjoining property, which they thoroughly prospected. In the

The Old and the New at El Cobre Mine.



A Battery of Modern Boilers at El Cobre.



"Californias" for Moving of Copper from Mine Waters, at El Cobre.

Punta Sal Smelter.

latter part of 1906 a huge blow-out, or surface deposit of copper ore was found, from which 64,000 tons of 6% ore was mined and shipped to New York. In addition, systematic exploration resulted in the mining of 100,000 tons of 8.7% ore from the area above the 200 foot level. This ore has all been shipped to the United States for smelting, where remarkably good rates were secured and substantial profits made.

The mine is at present producing from 3,000 to 4,000 tons of ore per month, and exploration is once more being actively prosecuted with the object of again attempting to un-water this wonderful old mine in order to reach the 1,200 foot level, supposed to be the lowest level in the property.

The character of the ore deposit has been very fully described in an excellent paper written by the manager of the property, Mr. E. H. Emerson, and this description I present as a part of this paper.

CHARACTER OF THE ORE DEPOSIT.

The strike of the ore bodies is with the valley, northeast and southwest. A series of rocks, from a coarse agglomerate to a fine grained rhyolite without definite boundaries, constitutes the country rock of the deposit. The entire region is volcanic, traces of sediments occurring only on the summits of the surrounding mountains. One main fault, with several lesser parallel faults, striking with the formation, is responsible for the deposit. The main fault dips slightly to the south and carries a mud seam 3 inches to 5 feet width. It presents a straight, smooth surface in many places in the mine. Another nearly parallel fault 300 feet to the north, called the North Vein, dips to meet the main fault at 1,000 feet in depth. To the south are a series of lesser faults that diverge from the main formation at the east end of the property, and extend along the side of the mountain range for a mile.

The main fault formed what has been called the Middle Vein. This is a series of lenses of ore in brecciated zones on both sides of the fault, sometimes touching it and sometimes separated from it by many feet of rock. These lenses are irregular and are cut off by slips and joints without presenting regular walls, while the other faults have produced veins with clean walls, though varying greatly in width. A transverse fault zone has caused a 50 foot

throw of the Middle and North Veins. Along this zone, and near it, occur the greatest bodies in both veins. The widest lense is 125 feet, and they are almost continuous for a half mile with varying widths.

The veins, with clean walls and rarely exceeding twenty feet in width, were well worked by the stull-timber; but caving and slice filling have recovered much ore lost by the old methods in the lenses.

The gossan extends, pretty generally, to a depth of 100 feet, carrying pockets of very rich oxides; but it is noticeable that there is a barren zone of gossan for 10 to 30 feet above the rich sulphides.

Near the surface, and close to the transverse fault between the veins, a brecciated zone was found in the agglomerate. This was filled with oxides, cracks being filled with a network of criss-cross stringers averaging an inch in width, and the mineral also impregnated the leached, almost kaolinized, agglomerate. The rotted rock was easily separated from the harder stringers of oxides, and 10 to 15 tons of barren rock was handled and hand-picked, producing one ton of 10 to 12 per cent. ore at a good margin of profit. This was worked from open cut and by slice-filling from below.

Pyrite, in perfect separate crystals, is common in great areas of the agglomerate, and much of the country rock shows stringers of gypsum.

The North Vein, to the east of the transverse fault and at the 500 foot level, showed a very abrupt change, from the enriched tarnished chalcopyrite with silicious gangue, to a clean bright chalcopyrite with a pure gypsum gangue. Extending with lessening values to the 700 foot level, the vein became pure white gypsum with only an occasional piece of ore. At the same time the lenses along the main fault continued with enriched sulphides and quartz without a trace of gypsum, and the North Vein, to the west of the transverse fault, showed no gypsum.

The depth of the enriched zone of the sulphides has never been determined. It occupies at least the area from the 100 foot level to below the 650 foot level. In this area large lenses of fresh $3\frac{1}{2}\%$ ore contain chutes of very rich sulphides. A stope on the 550 foot level was supplying 22% ore at the time of the cave-in.

Spanish American Iron Co's Mines at Daiquiri.

The depth of the lowest workings of the old companies is variously estimated at from 1,000 feet to 1,200 feet, and, as only rich ore could be handled at that time it may be assumed that the enriched zone extends to that depth.

All ores of copper are found from the red and black oxides and native copper in the gossan, through native copper, in considerable quantities in the top of the sulphides, and all the sulphides down to clean chalcopyrite.

The ore is highly silicious (from 45% to 65% excess insoluble) carrying only 20 cents gold and ½ oz. silver. It is very free from impurities.

The veins become tight to the east, and although joined by the southern veins of the Santiago Hill, have shown no values of importance to the east of the Cobre River. At the west end they are cut off by a massive igneous intrusion. Two agglomerate hills extend, with the same strike, to the west as though the vein-formation has been faulted to the north. Pyrite is very prevalent; but no copper of importance is met with.

The Santiago veins were narrow and appeared to pinch in depth. The only important ore on the Santiago Hill, worked by the Cuba Copper Company, was a peculiar pocket of ore formed by the intersection of the Santiago vein with a band of leached pyrite in the porphyry. The deposition of copper oxides and carbonates followed the spherical lines of weathering of the porphyry, forming an unusual and striking ore of spotted and striped black, red and green in a white weathered porphyry matrix, which was well called "Tiger ore" at the smelters.

It is peculiar that at the west end of the main Cobre veins, which show only a trace of gold and no impurities, a small vein of zinc-blend, chalcocite and pyrite, carrying $15.00 in gold, should occur. This vein has the general direction of the others and is only 175 feet deep, 200 feet long, and about 10 feet wide in its widest place. It is a little to the north of the main veins and cut off, as they are, to the west.

The total production of the property can only be approximated. It is, however, known that a million tons of ore and 140,000 tons of copper have been shipped from the property since 1830.

El Cobre has always been handicapped by the extremely silicious character of its ore. A systematic attempt is now being

made to develop a basic ore on the Island, for utilization in conjunction with the Cobre ores. Should this attempt be successful, El Cobre may again take her place among the important producing mines and add another page to her varied history, which already covers a period of 375 years.

ROCKS OF EL COBRE.

Agglomerate.—Sharp angular pieces from pebble to fist size, cemented by a bluish material very silicious. Blocks have the appearance of concrete. Easily rotted and changed to Kaoiln near surface.

Breccia.—Rhyolite and porphyry breccia, occurring throughout the agglomerate without defined boundaries. Fine grained, light gray and reddish.

Rhyolite.—Gray, fine grained and in depth glassy.

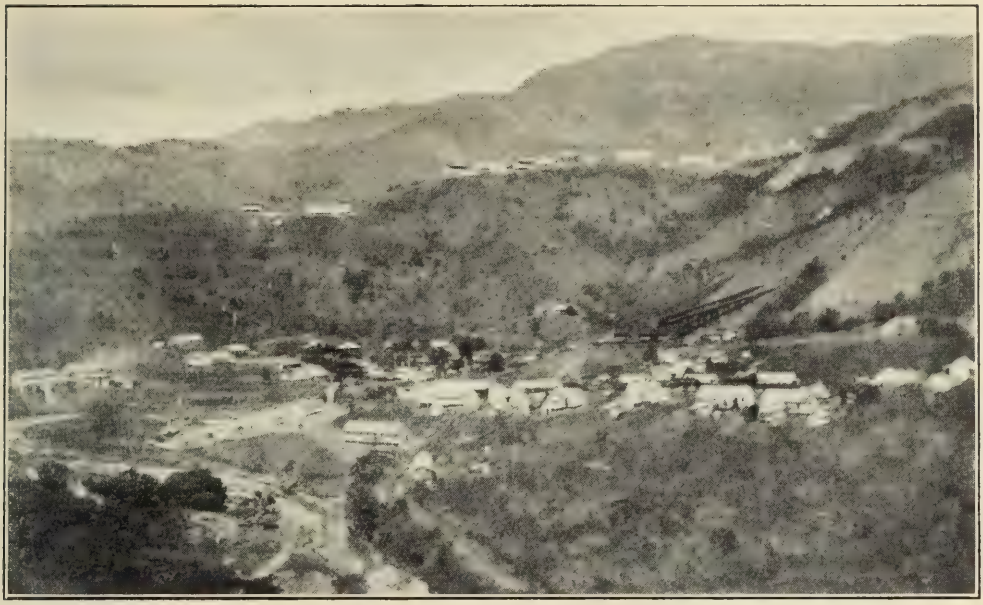
Tuff.—Rhyolite, tuff occurring with the rhyolite. Easily rotted to white near surface.

Massive Intrusive.—A coarse grained porphyry. Iron stained in weathering from contained pyrite.

SPANISH-AMERICAN IRON CO.

The second Cuban mine included under the title of this paper is that operated by the Spanish-American Mine Company situated 26 miles from Santiago de Cuba. It was first opened in 1889, and is now producing some 540,000 tons a year of hematite containing 58% iron, ·02 phosphorus and ·25 sulphur.

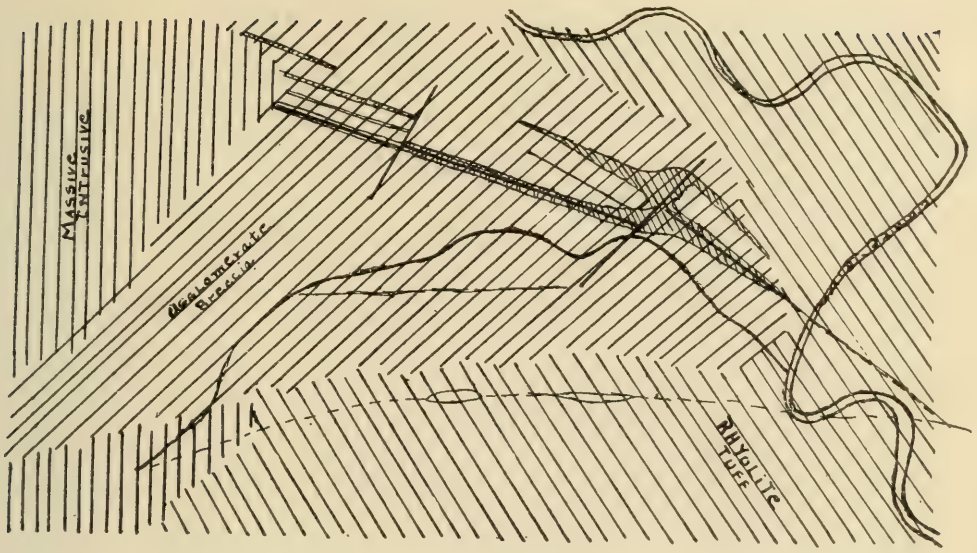
The deposit is on a side hill, and has been attacked by a series of benches, as shown in the accompanying photographs. The over-burden, or the top of the hill, about 100 feet in all, was first removed, and the ore attacked in the method described. The deposit itself seems to be a lens, or a series of lenses, in cyanite. The ore is brought to Daiquiri, made notable during the Spanish-American war, and then to the ocean in cars of standard gauge. After being crushed just below the mine, the ore is again picked up from the stock pile and loaded into steamers from the company's piers.



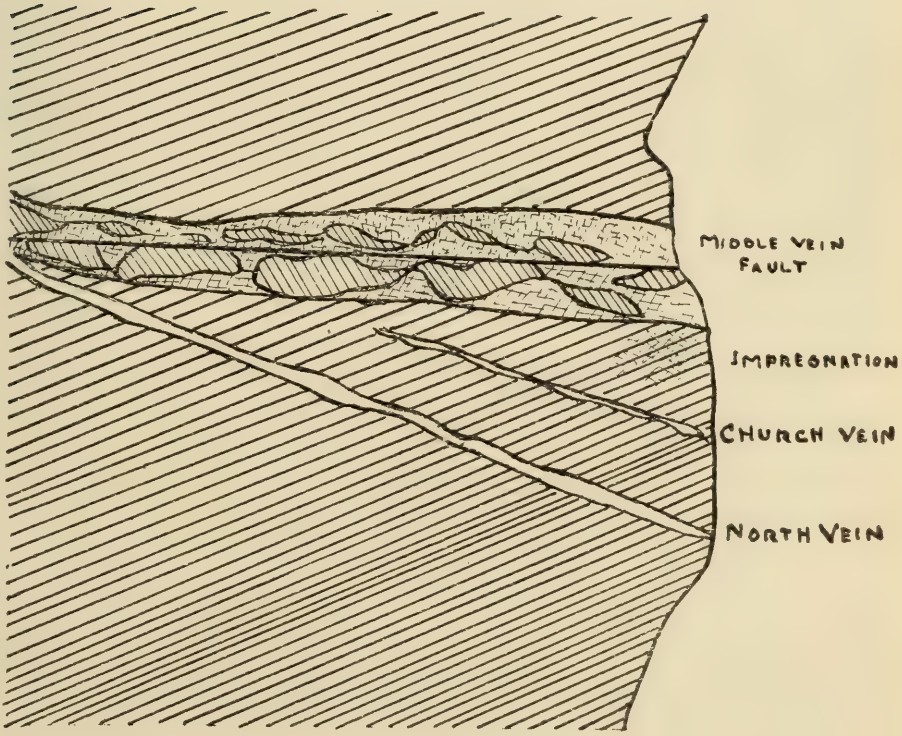
The Town of Daiquiri.

Shovel Method of Loading Iron Ore, where harbour facilities are inadequate.

Mining at Daiçpūri.



EL COBRE VEINS
Scale 1" = 1000'



CROSS SECTION OF EL COBRE VEIN.

This company has also recently developed a very important iron ore deposit at Mayari, on the north coast, with a part 12 miles away at Nipe Bay. This iron ore is peculiar inasmuch as it occurs directly on the surface to a depth of some 30 feet, and is said to be the result of a decomposition of the serpentine and the enriching of a zone of iron ore.

A complete analysis of a general sample gave the following results:—

Iron, after drying at 212 deg. F.	46·03%
Silica	5·50%
Alumina	10·33%
Chromium	1·73%
Phosphorus	·015%
Hydroscopic water	31·62%
Nickel	1·04%

It is apparently a secondary enrichment, and the ore covers the entire plateau for some miles. It is estimated that there are one billion tons of ore in sight.

The handling of this ore is interesting. It is first steam-shovelled into railroad cars of standard gauge of 50 tons capacity. These railroad cars are brought to the top of an incline and lowered three miles. Here the ore is dumped by electric crane into a stock pile, and from there taken by a clam-shell shovel to the furnaces, where the water is driven off and the ore is nodulized. The ore is heated by coal to a high temperature, water is driven off, and the material is loaded into vessels to be shipped to the United States.

The plant is capable of handling about 5,000 tons per day at an estimated cost of $1.01 as follows:—

Mining	11 cents
Hauling	15 "
Nodulizing	75 "
Total	$1.01

There are several other very interesting mining operations on the Island of Cuba, both in copper and iron.

DISCUSSION.

DR. DOUGLAS:—Mr. Lawrence has touched on the recent history of copper mining. I think he might have gone back to even pre-Columbian time in his story of this interesting old copper mine. There is every reason to suppose that these copper ores were utilized before the discovery of America. Mr. Clarence Moore, who had been doing a great deal of archeological work in Florida and elsewhere wrote to me some years ago to ask if I knew anything of a native alloy of lead and copper in New Mexico. I told him I did not think there was any such thing in the world—I was very sure that there was no such thing in New Mexico. He said he had been informed that such a native alloy existed only in New Mexico; adding that he had discovered some copper implements in the mounds of Florida, that had been made from such an alloy of lead and copper; hence the deduction that there was a commerce in those pre-Columbian days between New Mexico and Florida. I told him I thought it was a mistake, and that his chemist had some how or other blundered, and I advised him to send his samples to Dr. Ledoux, who would probably form some other theory to account for the copper found in those mounds. He sent the samples to Dr. Ledoux, and Dr. Ledoux of course found that there was absolutely no lead in the copper, but that it was remarkably pure copper.

The question, therefore, was where did the copper come from? I told Mr. Moore that I thought the copper came from whatever region produced copper of exactly that description. It was extremely free from arsenic, and free from antimony. If it had come from the lakes it would contain a certain amount of gold and silver. Of course we all know that copper was mined in Michigan by the natives before the discovery of America, and that it was transported almost over the continent. I suggested to Mr. Moore that possibly the copper may have come from those old Cuban mines, because Columbus on, I think, his third journey, mentioned having seen some natives, from what he supposed to be Asia, who were navigating a very large canoe and carrying on some commerce between the Island of Cuba and the Asiatic shore. I advised Mr. Moore to get some samples of native copper if he could from the outcrop of this Cuban mine at Cobre. He

did so, and Dr. Ledoux found that the analysis corresponded absolutely with the copper that he had exhumed from these old mounds.

The conclusion, therefore, I believe, is that these mines were worked in pre-Columbian time, and that there was a commerce in copper between the island of Cuba and the continent of America and that now, after so many vicissitudes—political and economical—we are only reviving an old industry, that was active more than three centuries ago.

DR. J. D. IRVING:—Mr. Lawrence's reference to both of these mines has been very interesting to me—the first reference particularly, because it deals with a question to which I have lately devoted considerable thought and concerning which Mr. Ransome read a paper yesterday—that is, in regard to secondary enrichment of ore deposits in their relation to climatic conditions.

In the course of some experimental work that I had an opportunity of doing in Alaska, I found that a great many outcrops of cuperiferous pyrite were absolutely unoxidized at the surface. The waters of that northern climate were so cold that there had apparently been no opportunity for deep oxidation to occur. Sulphides extended actually to the surface, and there had been apparently no opportunity for leaching to go to any depth. Even in the stream beds themselves there were present particles of sulphides of iron and to some extent cuperiferous pyrites, that were not oxidized by the running water of the streams.

Coming further south to a region of temperate climate, we find a great contrast in the deep secondary enrichment at Butte, Montana. Finally, in tropical countries such as Cuba, we find the conditions that Mr. Lawrence has encountered in the mine which he has just described. I am especially anxious to know the details of oxidation here because it has been very difficult for many of us geologists to get much information as to the depth of oxidation under tropical conditions. Generally the chemical changes may be assumed to extend to much greater depths than farther north, provided the level of standing water is itself sufficiently deep. I should like to ask Mr. Lawrence if he can give me any details on the level of ground water in the mine at the time it was pumped out and the relation in depth, of oxide, secondary sulphide and primary sulphide zones to this line.

MR. LAWRENCE:—I suppose the effect of climatic conditions upon copper ore in Cuba can best be illustrated by one of the numerous catastrophies that seem to have followed the operations there.

A stock pile of copper amounting to some thirty five thousand tons was placed at the harbour. The stock pile was uncovered and subjected to action of rains for a year. It was partly oxidized ore and partly sulphide ore. Some of the ore that came from the lower levels was clean chalcopyrite, and some from the upper levels was oxidized. When the ore was finally shipped to New York it showed that it had lost one half of one per cent in copper. We found on investigation that oxidation had been going on in this stock pile rapidly all the time. On digging a hole in the stock pile you could hardly hold your hand in it on account of the heat generated by oxidation. Every rain that fell on that stock pile carried away a substantial amount of copper.

The same operation, I think, happened in the upper portions of this copper mine, and the oxidized area extends approximately 200 feet to the enrichment zone. The gossan extends generally to a depth of one hundred feet, carrying pockets of very rich oxide, and it is noticeable that there is a barren zone of gossan ten to thirty feet from the surface above the rich zone.

The geology of this mine has still to be studied from its lower levels and as yet this history has not been written.

DR. IRVING:—There is just one point on which I should like information: What was the average level of the surface of the water as it stood in the mine when you commenced operations?

MR. LAWRENCE:—Well, I cannot positively say as to that. They have been holding the water at the 200 feet level for many years, and that would have been fairly well up in the oxidized zone.

MR. DRESSER:—The iron ores associated with serpentine, which have been so interestingly described by Mr. Lawrence, suggest a comparison with some bodies of magnetite that occur in the serpentines of southern Quebec and northern Vermont. In the latter place they were worked for some time about sixty years ago.

In the Cuban deposits the ores are in beds; but in the northern areas they form lenticular masses. This difference is doubtless

due to the glaciation of the northern part of the continent, that did not extend to Cuba. In Cuba long erosion seems to have resulted in an accumulation of the ores *in situ*, while in the northern regions such concentrated deposits, if they ever existed, have been swept away by the glacier, and only such an amount of ore remains as is normal to the rock. The deposits of Quebec and Vermont are generally regarded as primary segregations of the original rock, perhaps modified by solution and re-depositions. It seems possible also that an additional source of iron may be found in the origin of the serpentine. Serpentine—magnesium silicate—is derived largely from the alteration of olivine, which is a silicate of magnesium and iron. Iron is thus set free in the process, which may account in part for the presence of iron deposits in serpentines.

MR. COSTE:—May I ask Mr. Lawrence if he can give us the analyses of the nodules?

MR. LAWRENCE:—I am sorry to say I cannot do so. The analysis given to me were only of the material before it was nodulized. I believe the percentage of chromium is quite considerable and requires a further process. The percentage of nickel is five tenths of one per cent.

MR. COSTE:—How much iron was there in the nodules?

MR. LAWRENCE:—I suppose they bring that up to a fair grade of iron, say 63 or 65%, or up to what might be called an average hematite. It may be as high as 70%.

MR. COSTE:—Mr. President, may I be allowed to voice the appreciation of the members of the Institute for the interesting remarks of Mr. Lawrence and to offer him our thanks for his paper? (Applause).

MAGNETITE DEPOSITS OF TEXADA AND VANCOUVER ISLANDS.*

By E. LINDEMAN, Ottawa, Ont.

(Annual Meeting, Toronto, 1909).

A general reconnaissance of the iron ore deposits of Texada and Vancouver Islands was undertaken by the writer during the field-season of 1907, and the following paper is based on data then obtained.

General Geological Features.—Geologically the areas surrounding the magnetite deposits present a series of metamorphic rocks, argillites and quartzites, associated with crystalline limestone, and resting upon or intruded by hornblendic granite or other eruptives. All these rocks have been named the "Vancouver Series" and referred to the Triassic age by the late Dr. G. M. Dawson.†

The similarity of the geological conditions of the various ore bodies is remarkable, as all the deposits occur along or adjacent to the contacts of the crystalline limestone and the igneous rocks, occupying here irregular interspaces of very variable dimensions. The general appearance seems to indicate that the formation of the magnetite occurred contemporaneously with the intrusion of the eruptive rocks and has been dependent on the effects produced by that intrusion.

The ore bodies are usually found on the end or flank of a ridge, following roughly the contour of the hill and sometimes rising as much as 50 to 100 feet above the base of the outcrop. Fragments of the ore have often fallen down the slopes giving an impression

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* By permission of the Director of the Mines Branch of the Department of Mines.

† See Report of the Geological Survey of Canada for 1886.

that the ore-body occupies a larger area than it really does. The area at the surface of the various deposits varies from a few square feet up to 30,000 square feet. One of the deposits on Texada Island has been proved by drifting to a depth of 430 feet; while similar development on some of the deposits of Vancouver Island show a depth of 50 to 100 feet.

Character of Ore.—Analyses of average samples taken by the writer from various deposits show a content of metallic iron ranging from 58 to 67 per cent. The phosphorous content is low, most of the samples showing a percentage considerably below the Bessemer limit. The sulphur content is, on the other hand, high and local abundance of sulphides is very common. A thorough roasting of the ore might therefore be necessary.

Industrial Prospects.—Though no actual figures as to the ore in sight can be given, it is still certain, that a considerable tonnage of merchantable magnetite is available on some of the properties of Texada and Vancouver Islands that can be mined under favourable circumstances. The deposits are all situated close to or within reasonable distance of navigable waters. The limestone associated with the magnetite is exceptionally pure and free from injurious elements. From several well developed collieries on Vancouver Island a large tonnage of coal is now mined, some of which is suitable for coke making. Therefore, with all the required raw materials available and favourably situated in regard to transportation, an iron industry on the coast of British Columbia seems to be feasible, provided that a sufficient market for its product can be secured. This may not be possible at present, but, with the rapid development now proceeding in the West, the time cannot be far distant, when Western Canadian demand for iron will warrant such an industry.

Until then, a market for the magnetite of Texada and Vancouver Islands is likely to be found in the adjacent state of Washington, where an iron industry is now under development.

TEXADA ISLAND DEPOSITS.

The iron ore deposits occurring on the western slope of Texada Island, from three to four miles north of Gillies bay, have been known for many years, and were acquired for iron mining

Sketch Map of Vancouver Island.

as early as 1875. The principal ore deposits are on the Prescott, Paxton and Lake properties.

The *Prescott* mine has been the most largely developed, and has during several years shipped ore to Irondale, Washington. The magnetite outcrops about 850 feet from the shore, in a big bluff on the brow of a steep and rocky hill, at the contact between granite and crystalline limestone. The deposit has been opened at three levels. At an elevation of 365 feet, an open-cut had been made into the hill, showing magnetite, penetrated by granitic dykes. Sulphides of copper and iron are also common here. The second level is situated 40 feet above the first. A considerable amount of ore has been taken out from an open-cut, that shows a face of magnetite 40 feet wide and about 100 feet high.

The ore includes small patches of calcite, and fragments of volcanic rocks, forming in places a species of iron breccia. Sulphides of copper and iron, are also present, in a greater or smaller degree. An average sample from the ore dumps gave the following analysis:—

	Per Cent.
Insoluble matter	6·46
Iron	62·57
Sulphur	0·403
Phosphorus	0·024

The third level is situated 60 feet above the second, at an elevation of 465 feet above sea level. The cut has been made following the strike of the ore body, and the face of it is about 50 feet high and 50 feet wide, showing the same kind of ore as at the second level. With some handsorting the ore will give a good merchantable magnetite. An average sample of the ore dumps gave:—

	Per Cent.
Insoluble matter	12·00
Iron	58·76
Sulphur	0·113
Phosphorus	0·011

Between the second and the third level the ore was traced along the hill for about 200 feet, its width on the third level was about 80 feet.

About 430 feet below the top of the bluff, and at about 130 feet above sea level, a tunnel was driven into the hill, below the quarries. The length of the tunnel is 630 feet, passing through granite, and showing solid magnetite for the last 75 feet on the west side of the tunnel, and for 45 feet on the east side. By means of this tunnel the depth of the ore has been demonstrated to be at least 430 feet, while the quality of the ore is proved to be not inferior to that of the upper levels.

An average sample of the ore taken along the tunnel gave the following analysis:—

	Per Cent.	
SiO_2	4·37	
FeO	28·09	Iron 63·27
Fe_2O_3	60·60	
Al_2O_3	1·18	
CaO	2·58	
MgO	1·05	
Cu	0·09	
S	0·347	
P_2O_5	0·013	

From the Prescott mine the contact between the limestone and the eruptive rocks, though in many cases covered by a sandy loam, can be traced for about 1,200 feet further up the hill, and after again making a sharp bend down hill for about 800 feet, it takes a more easterly course, making some windings, to the Paxton mine and then to the Lake mine. Strong magnetic attraction in some places, and numerous outcrops of magnetite, were noted along this contact, some of the outcrops reaching a width of about 70 feet.

The *Paxton* mine is situated about 3,500 feet east of the Prescott mine. Some outcrops of magnetite extend along the face of a ridge for about 500 feet. This deposit has been exploited by two open-cuts passing through granite, which seems to form the hanging wall, and then into the ore. None of the cuts have been driven entirely through the ore body, so that it is not possible to determine its full width. From the face of the east open-cut a tunnel 45 feet long has been driven in the same direction as the cut, and showed solid magnetite, carrying some sulphides of copper and iron.

An average sample taken along the tunnel gave the following analysis:—

	Per Cent.
SiO_2	4·47
Fe	64·48
Al_2O_3	0·66
CaO	1·32
MgO	1·13
Cu	0·22
S	1·866
P_2O_5	0·005

The *Lake* mine is situated about 1,300 feet to the east of the Paxton. The ore can be traced along the face and brow of a ridge for some 200 feet. The height of the ore bluff is about 80 feet, with a maximum width on the surface of about 100 feet. An open-cut had been made in the ore body, showing a good clean magnetite. About 1,000 tons of ore are reported to have been shipped to Irondale, Washington, during the summer of 1906.

An average sample of the ore gave the following analysis:—

	Per Cent.	
SiO_2	8·33	
FeO	25·07	Fe 59·57
Fe_2O_3	57·96	
Al_2O_3	1·71	
CaO	3·82	
MgO	1·05	
Cu	0·08	
S	0·137	
P_2O_5	0·057	

Though it is impossible to make even an approximate estimate of the ore in sight on these properties in Texada Island, because sufficient development has not been done to warrant such an estimate, there is every possibility of large quantities of merchantable magnetite being found. The properties are situated close to the water front, and a little bay offers good facilities for shipping. From none of the claims has the ore to be transported a greater distance than a mile and a-half, and in some cases considerably less.

QUINSAM RIVER.

The Quinsam is a tributary of the Campbell river, which flows into the Strait of Georgia at a point about 35 miles north of Comox, and directly opposite the south end of Valdes Island. The mineral claims are situated on a tributary of the Quinsam, about 13 miles from the coast.

Magnetite outcrops here on the north bank of the river, in a bluff about 80 feet high. Part of the face of this bluff has been stripped for 53 feet in width (showing solid magnetite) without having uncovered the contacts with the country rock. About 40 feet above the river a tunnel had been driven into the hill following the strike of the ore. The tunnel was 60 feet long, entirely in magnetite.

A sample taken along the tunnel gave the following analysis:—

	Per Cent.	
SiO_2	7·00	
FeO	22·82	Iron 56·45
Fe_2O_3	56·71	
Al_2O_3	2·07	
CaO	3·77	
MgO	1·25	
P_2O_5	0·03	
S	0·53	
Cu	0·70	

Another sample taken across the face of the bluff above the tunnel, gave the following analysis:—

	Per Cent.
Insoluble matter	11·00
Iron	59·77
Sulphur	0·533
Phosphorus	0·024

Following the crest in a north-northwest direction, some outcrops and surface strippings were noted. These indications, and strong magnetic attraction, show the ore to be continuous for a distance of about 350 feet. The ore is generally free from admixture with country rock, though containing some sulphides of copper and iron.

KLAANCH RIVER.

Nimpkish lake is fifteen miles in length, and has an average width of rather less than one mile. It empties at the north end through Nimpkish river into Broughton Strait, at a point directly opposite Alert bay. At the south end Klaanch river flows into the lake from the southeast. About seven miles up this river and on the south side of it, several claims have been staked, showing some magnetite. The most interesting of these prospects is, however, *Iron Crown* mineral claim. An exposure of magnetite extends along the face of the river bank for some 180 feet. The height of the bank is about 80 or 100 feet, forming at some points, cliffs of magnetite 25 to 30 feet high. A sample of the ore gave the following analysis:—

	Per Cent.
Insoluble matter	4·12
Iron	64·23
Sulphur	0·233
Phosphorus	0·010

Further up the hill, about 650 feet from the river, several outcrops of magnetite occur along the ridge. An average sample from these gave the following analysis:—

	Per Cent.	
SiO_2	5·30	
FeO	26·70	Fe 63·89
Fe_2O_3	61·56	
Al_2O_3	1·74	
CaO	0·80	
MgO	1·86	
Cu	trace	
S	0·017	
P_2O_5	0·037	

The solid formation being effectively covered by a sandy loam and a heavy vegetation, the outcrops mentioned were all that could be seen, but as the dip-needle showed a very strong magnetic attraction in several places, it was found advisable to make a magnetic survey to get some information in regard to the extent of the ore bodies.

This survey indicated the occurrence of three separate deposits or groups of deposits, which for reference were numbered I, II, and III.

No. I outcrops on the river bank as before stated. The top of the bank is covered with soil, and no work has been done to ascertain the width of the deposit; but to judge from the magnetic curves, and outcrops available, the width at the west end may be estimated at not less than 100 feet. The length of the ore body may be assumed to be about 190 feet.

Group II is the most important, and may be assumed to consist of two, possibly three, ore lenses, not counting the small pockets in the southern part of the group. The largest of these ore lenses has a length of at least 380 feet; a width of 60 feet is very probable, and in some cases it may be even greater.

Group III is altogether covered by soil. The magnetic survey showed, however, the ore strikes to be about parallel with the former group, with a length of about 480 feet, and a width which, in places, may be assumed to be very little less than that of the former.

HEAD BAY.

Head bay forms the upper end of Tlupana arm, Nootka Sound. On a ridge running northwest and southeast, four outcrops of magnetite can be seen at intervals, along a contact of crystalline limestone and diorite, about a mile from deep water in the bay. These outcrops are from 170 to 200 feet long, and have a maximum width of 40 to 55 feet. A little farther south, several smaller outcrops were noted, showing that there is here undoubtedly strong iron mineralization. Up to the present time, however, no work has been done to show the extent of the ore, with the exception of one place where some stripping had been done, and an open-cut made at right angles to the strike of the ore into the hill, exposing the ore for about 55 feet. The ore is of good character, and an average sample, taken along the cut, shows:—

	Per cent.	
SiO_2	6·10	
FeO	28·61	Fe
FeO_3	62·24	66·17
Al_2O_3	0·35	
Ca_2O_3	1·15	
MgO	0·44	
Cu	trace.	
S	0·017	
P	0·016	

GORDON RIVER DISTRICT.

The Gordon river flows from the north into Port Renfrew, or Port San Juan, as it is locally known, which is about 60 miles from Victoria on the west coast of Vancouver Island. A considerable number of mineral locations covering showings of magnetite have been made here.

The Baden-Powell and Little Bobs mineral claims are situated up the Gordon valley about seven miles from salt water. An outcrop of magnetite is found on the flank of a ridge, along which it can be traced for 350 feet. About 90 feet below the top of this outcrop contact a tunnel 114 feet long had been run directly into the hill, showing magnetite for its full length, with the exception of a diorite dike eight feet wide about 30 feet from the mouth of the tunnel.

An average sample of the ore taken along the tunnel gave the following analysis:—

	Per Cent.
Insoluble matter	8·88
Iron	58·30
Sulphur	2·75
Phosphorus	0·013

About thirty-five or forty feet below this tunnel another tunnel had been driven in the same direction for 114 feet into the hill, passing through limestone and diorite. The last few feet, however, show magnetite dipping in towards the hill.

The *Sirdar* mineral claim is situated two miles farther up the valley, and the occurrence is very similar to those of Baden-Powell

and Little Bobs. The magnetite outcrops along the face and brow of a ridge for about 160 feet. About fifty feet below the top of the ridge a tunnel had been driven 103 feet into the hill, showing the width of the ore to be about eighty-two feet. An average sample taken along the tunnel gave the following analysis:—

	Per Cent.
Insoluble matter	8·52
Iron	56·57
Sulphur	2·75
Phosphorus	0·121

The Conquerer mineral claim is situated a little farther up the valley on Bugaboo creek, which flows into the Gordon river. The claim is some nine miles from the navigable waters of Port San Juan. A solid body of magnetite about forty feet high is exposed in the canyon of the creek, and over which the creek forms a water-fall. The ore has a maximum width of about sixty-three feet on the east side of the creek, but becomes narrower on the west side. On the east side, the ore body is stripped for about eighty feet from the creek to where it passes into the gravel bank. At the foot of the bluff a tunnel fourteen feet long had been run into the ore, showing solid magnetite. A sample taken along the tunnel gave the following analysis:—

	Per Cent.
Insoluble matter	4·51
Iron	67·09
Sulphur	1·60
Phosphorus	0·009

On the up stream side the ore body is confined by a diorite dike, six feet wide, crossing the creek nearly at right angles. Beyond this dike, outcrops of magnetite were noticed on both banks of the creek for a distance of about sixty feet, and on the east side for fifteen feet farther. Here, however, the ore seems to lie as a blanket on top of a green igneous rock. A couple of hundred feet east of the creek some outcrops of magnetite were reported to have been struck by strippings, but the workings had caved in at the time of the writer's visit. Between these strippings and the creek a strong magnetic attraction was noticed in several places. From the existing development, it was, however, im-

possible by superficial examination to secure any exact information as to the extent of the ore body, or bodies, as the solid formation is effectually covered by a sandy loam.

The same may be said concerning the *David* mineral claim, east of the Conqueror, and adjoining Sirdar on the west side. Within a distance of 400 feet along a slope, some strippings have exposed a good magnetite in several places, but do not give sufficient information to warrant an estimate of the extent of the ore.

DISCUSSION.

THE PRESIDENT:—Mr. Lindeman has given us a very interesting paper. The iron deposits on the Pacific coast here referred to are the first to be examined in anything like detail, and the facts presented are therefore all the more valuable on that account.

THE SECRETARY:—I would like to ask Mr. Lindeman if he has any data with regard to recent industrial developments in British Columbia? It is reported that iron and steel works are about to be established near Vancouver.

MR. LINDEMAN:—I have no information on that point.

THE SECRETARY:—Can you express any opinion on the subject of market possibilities for iron or steel manufactured from British Columbia ores?

MR. LINDEMAN:—A few years ago I endeavored to investigate this matter and found that the importation of pig iron to British Columbia then represented about 2,000 tons annually. It would appear that the market requirements are not sufficient for the maintenance of an iron industry.

MR. J. C. MURRAY:—Is there not a possibility of developing a market in the Western United States?

MR. LINDEMAN:—The duty on pig iron imported to U.S.A. is at present $4 per ton. Owing to this and also to the fact that an iron industry is now under development in the State of Washington, I am afraid it would not be possible for a British Columbia furnace to market its products profitably in the Western States.

MR. A. B. WILLMOTT:—It was my good fortune to visit, last autumn, some of the deposits described by Mr. Lindeman, and I should like to bear testimony to the magnitude of the magnetite deposits occurring in British Columbia. You must have noticed that Mr. Lindeman showed in his analyses that they are very low in phosphorous contents. It is true they are somewhat high in sulphur, and it is rather striking that so many of them contain copper. There are others, not mentioned in this paper, that have been "taken up" as copper deposits, and these are being prospected for copper in what are really low grade magnetite bodies. Apparently, in some of these deposits there is neither copper nor iron in sufficient quantity to be of commercial value. In others the copper could be hand sorted, and the balance of it roasted.

Now, answering some of the questions put to Mr. Lindeman, I think it would be quite possible for an iron industry, if established in British Columbia, to successfully compete in the American markets. Pig iron for the Pacific United States is chiefly supplied from Chicago; a little is derived from Colorado. The freight rate from Chicago on pig iron is about $15 a ton. This is a great deal more than the duty of $4 per ton that would be levied on iron manufactured in British Columbia. Hence, it seems to me, it would be quite possible for an industry located in British Columbia to market pig iron profitably in Washington and Oregon.

British Columbia has natural facilities for the manufacture of iron. These are quite equal, probably, to those in the province of Nova Scotia. Thus, the iron ore is there, the coal is there, and the limestone is there. Labour is expensive and, of course, the market is at present limited. That market is a great deal larger than Mr. Lindeman indicated when he said that two thousand tons of pig iron were imported. It is impossible for local foundries to buy pig iron at $25 a ton and manufacture it into small articles in local demand in competition with foundries in the east. As long as pig iron stands at that very high figure, I do not see how you can have local foundries in British Columbia. I certainly believe that in a very few years you will see an iron industry established in British Columbia.

MR. HOBART:—I would like to point out the possibility of a considerable iron industry in British Columbia and a considerable trade with the United States. As Mr. Lindeman says, in his paper,

the Pacific coast has very little iron ore south of the boundary, and has also very little fuel. It is dependent on British Columbia for its coke and the best of its coal. Moreover, I can say that during the past year the imports not only of pig iron, but of finished iron—structural iron and steel from Germany and Belgium —on the Pacific coast, especially in San Francisco and Los Angeles, have been very heavy, and they have far exceeded the quantities supplied from the east to the State of California. If iron can be delivered there from Belgium and German profitably, it can surely be delivered from British Columbia, and, as Mr. Willmott remarks, the high freight rates overland from the eastern United States will be far greater than the duty on the iron from Canada into the United States.

DR. RANSOME:—There are a great many questions regarding the geological relations of these deposits as suggested by the paper just read, and I would like to ask Mr. Lindeman what the character of the intrusive rock is.

MR. LINDEMAN:—They are chiefly granites and diorites.

THE SECRETARY:—Incidentally it might be mentioned that the iron from Texada Island has been utilized in the United States for some years past to a limited extent, and it is a well known and interesting fact that in two United States warships built in San Francisco, most of the iron employed came from Texeda Island.

THE HELEN MINE, MICHIPICOTEN, ONT.

By R. W. SEELYE, Sault Ste. Marie, Ont.

(Annual Meeting, Toronto, 1910.)

During the summer of 1897, Ben Boyer, a prospector, found an outcrop of iron ore on the shore of a small lake located some twelve miles inland from Michipicoten Harbor, Lake Superior.

This lake, later known as Boyer Lake, with its greatest length less than one-half a mile, was situated over six hundred and fifty feet above Lake Superior, and surrounded by high hills on all sides, except for a small draw at the West, leading through to a second small lake, from which the overflow falls nearly vertically into Lake Talbot, one hundred and twenty-five feet below.

The past tense is used in describing Boyer Lake, for it has been pumped dry since the operation of the Helen Mine.

The hills forming the amphitheatre around Boyer Lake attain a further altitude of five hundred feet and so overlook Lake Superior from an altitude of nearly eleven hundred feet.

Boyer's discovery was made at the East end of the lake and at the very foot of the highest hill in the range and under which the ore seemed to dip.

Boyer's interest in this find was purchased by Mr. F. H Clergue and became the property of one of his Sault Companies—The Lake Superior Power Company.

During the year following the discovery a large amount of exploration work was done. This exploration work consisted of surface stripping, test pitting and diamond drilling. The result of this work showed a solid deposit of ore, with boundaries resting so that in the horizontal plane the shape was eliptical, with the shortest axis extending two hundred and fifty feet and the longest axis extending seven hundred feet.

The quality of the ore thus exposed proved to be a high grade non-Bessemer. The analysis of the ore being mined to-day is practically the same as that found near the surface and averages as follows:—

Fe 57·1588% Natural.
SiO_2, 4·00 at 212°
Sul. ·1134 at 212°
Phos. ·125 at 212°

This analysis would seem to represent a true hematite, yet the ore is brown and only at a few points has ore giving a red streak been found. The ore is porous and therefore is quickly reached by heat and flux in the furnace, and is in much demand at furnaces both in the United States and Canada. The ore has always brought the highest Lake Erie prices and the sales have only been limited by the output of the mine.

When the navigation season of 1900 closed and figures were compiled to show the source and amount of freight passing down Lake Superior, it was discovered that 65,000 tons of iron ore had been loaded and shipped from the port of Michipicoten. This ore was known as "Helen Ore" and came from the deposit discovered by Ben Boyer only three years before.

The progress made during that short period was interesting and most creditable to those who wrought the changes.

The plant installed at the Helen at the close of 1900 had a capacity of 2,000 tons per twenty-four hours. Rail communication had also been afforded by connection with Lake Superior by the Algoma Central Railway. This road was built along standard lines and equipped with five locomotives, one hundred and seventy-eight Carnegie pressed steel ore cars, having a total capacity of 9,000 tons, and some two hundred other cars for general railroad work. A twelve spout dock, with a capacity of 1,500 tons per hour had been constructed and the "Harbour" took on the air of a prosperous village with its round house, railroad shops, hotel, freight sheds, office building and dwellings.

GEOLOGICAL FEATURES.

Geologically, the Helen deposit and its surrounding formations are very interesting; but in the present paper only the more important features and those bearing on the commercial aspects of the case need be referred to.

As already stated, the greatest length of the Helen deposit is 700 feet from east to west. At the east end the ore-body is bounded by siderite running 34% or better in iron. To the north of the ore body proper there is a band of iron-stained silica and beyond this brecciated ferruginous chert. At the west end the deposit is intersected by a clayey dike cutting the iron formation from north to south, white in colour on the third level (260 feet below the surface) but becoming dark yellow near the surface. This is probably continuous with a dike of dark coloured medium grained diabase about 30 feet wide, that cuts the ferruginous chert to the north. This dike appears to form the barrier in the trough of iron formation against which the ore body was deposited.

An interesting feature of this ore deposit, is the presence in it of pockets of pyritic sand. Nearly all the sulphur in the ore shipped is derived from the pyrites "fines," as only a little hard pyrites is found disseminated in the hard ore. The pockets of pyritic sand vary in size from those representing a few cubic feet, to others varying from 30 to 40 feet in their greatest dimension. The proximity of these pockets can usually be foretold a few feet in advance by an apparent bedded character of the ore adjacent to them.

These pockets were not numerous in the first level, but as depth is attained the pyritic zone has increased in size. The occurrence of the pockets has proved troublesome in mining since when the pockets are accidentally opened the pyrites contaminates the good ore. Also, because it is necessary to carry drifts round the pockets in order to win all the good ore.

On the South side the ore-body is bounded by a clayey zone about 30 feet in thickness, beyond which lies a phase of the green schist series.

As greater depth is attained the major axis appears to decrease in length, but at the same time the minor axis increases in length. The ore-body has a gradual pitch a little North of East, the west boundary on the fifth level being about 150 feet east of the west boundary on the surface.

MINING METHODS AND PRACTICE.

When discovered, the original surface of the deposit rose to a height of about 100 feet above Boyer Lake. The portion above lake level was first mined in benches and the ore was loaded into railway cars with steam shovels.

Below the lake level and to a depth of 180 feet the deposit was worked as an open pit. The ore was hoisted to a large Austin crusher, that was placed above the railway tracks in such a way that the ore travelled by gravity into the shipping cars.

In working this open pit, an incline shaft was sunk in the ore-body to a depth of about 90 feet below the railway level. From the bottom of this shaft, drifts were carried in various directions to the limits of the merchantable ore. From the drifts, raises were made to the surface, and the ore was milled down the raises and trammed to the shaft.

As it was evident that open pit mining could not be carried to any great depth with safety, two vertical shafts were sunk in the country rock to the south of the ore-body. No. 1 being south and west end of the ore-body and No. 2,100 feet farther east.

Shaft No. 1 has two compartments, one for a cage and bucket, and the other for a ladderway, steam pipes, water line and air lines. Shaft No. 2 is used for hoisting ore only, and is a two compartment shaft, in which skips of two tons capacity run in counterbalance.

From these shafts, levels have been laid off as follows: Second at 180′, Third at 260′, Fourth at 320′, Fifth at 390′ and Sixth at 450′. Now only one shaft—the No. 2, is being sunk to reach the future levels. The size of this shaft has been increased so that below the Sixth level it will have four compartments.

The ore between the first and second levels was milled down to the second, thus giving an open pit to that level. Below the second level the ore is mined under-hand, pillars being left to support the back.

In laying out a new level, a main crosscut, wide enough for two tracks, is carried from No. 2 shaft into the ore-body. Timbering is necessary only along the clayey contact, which varies in width from 20′ to 30′. Once the main crosscut is well into the ore-body, a main drift 7′ x 7′ in section is turned off in an easterly direction about parallel to the greater axis of the deposit. Timbering is rarely necessary at any point within the ore-body.

As the main drift advances, crosscuts 7′ x 7′ are turned off to left and right alternately, at an angle of about 50 degrees with the main drift. This angle gives an easy curve for the tramming of ore from the stopes to the shaft. Crosscuts on the same side of the main drift parallel each other at a distance of 45′.

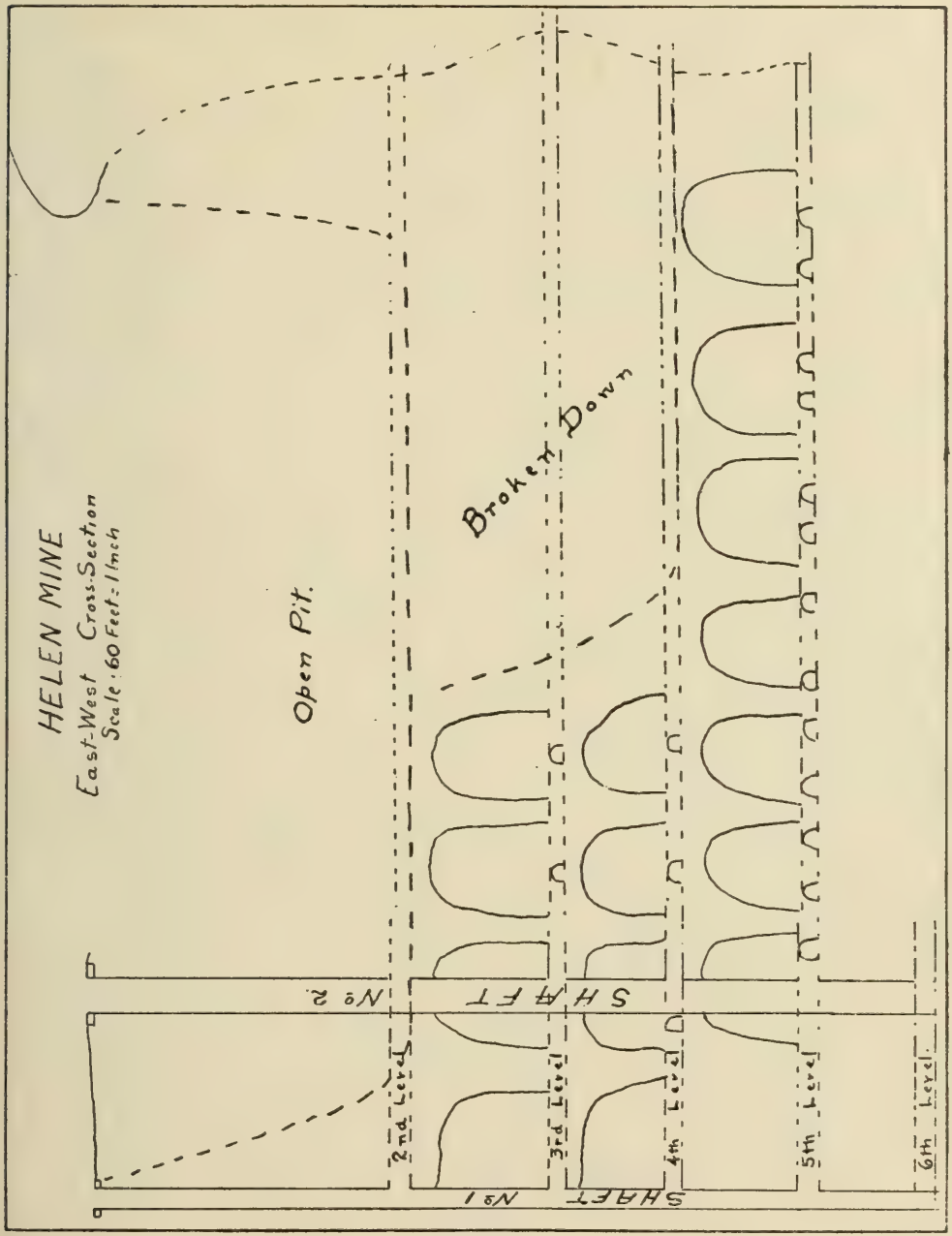


Fig. I.

As the crosscuts are carried forward, raises are put up at intervals of about 30′. These raises, which measure about 5′ x 5′ in section, are continued to within 12′ or 16′ of the floor of the level above, the thickness of back left depending on the nature of the ground encountered. As soon as the raises are up the proper distance, their tops are connected by a 5′ x 5′ cast which eventually forms the crown of the stope. Chutes or mills are built into the

lower opening of the raises and then the collars of the raises are broken down as long as the ore will travel by gravity through the mills into the tram cars. After that the mills are shot out and the ground worked down to the floor, care having been taken to leave at least a 15 foot wall between adjacent stopes. Where the ground is solid and will permit, cuts are made through the walls, thus leaving large pillars to support the back. These openings assist in the ventilating of the mine and the ore so won aids the output.

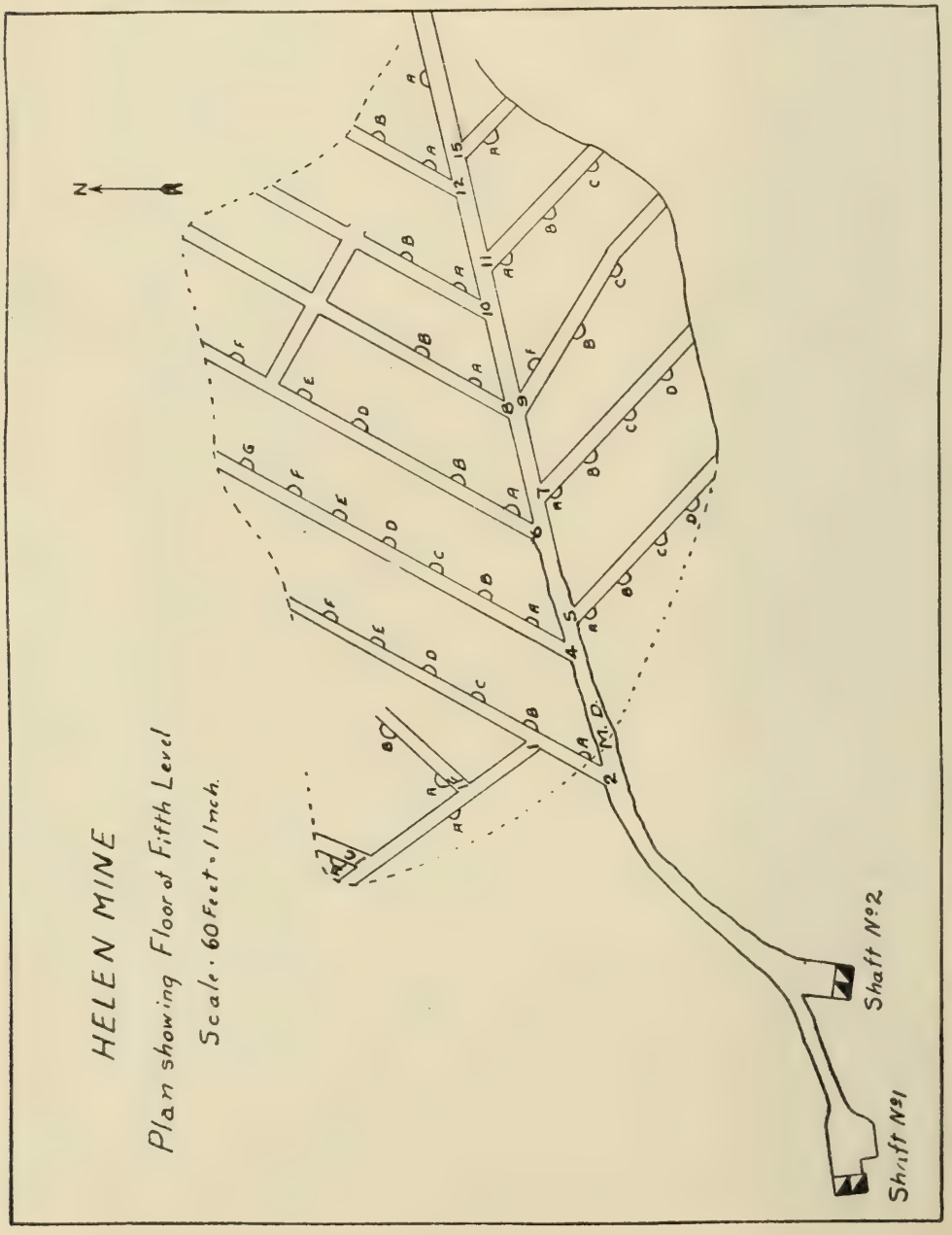


Fig. II

In both drifting and stoping No. 3¼ Rand drills operated by compressed air, are used exclusively. The miners are paid by contract, at so much per foot for drifting and raising, and at so much per car for stoping.

The ore, as stoped, is drawn off through the chutes into end-dump cars of 30 cubic feet capacity. These cars, which have wheels with 7″ face, travel on a 16″ guage track laid with 30 lb. rails. From the mine cars the ore is dumped directly into the skips in No. 2 shaft.

Two trammers handle a car. The trammers are paid a certain price per car, the price depending on whether the ore is drawn from chutes or shovelled and on the distance trammed.

Up to the present time, the method of opening up a new level has consisted of sinking No. 1 shaft to the depth required, and then drifting to a point directly under No. 2 shaft. A raise was then, put up to the skip, pit above, and the shaft squared down and timbered to the new level. In the meantime drifts were driven into the ore. Usually the No. 2 shaft would be completed about the same time as the ore would be cut on the new level. This method does not delay the skips in handling the output from the old level, and, at the same time, provides for taking all the ore from the new level direct to the crusher.

In the future, sinking will be undertaken in No 2 shaft only. The method will be to sink the "man-way" compartment 10 or 12 feet below the bottom of the skip pits and then cut over under the pits in such a way as to leave 10 or 12 feet of ground in place below the pits. This will protect the men while continuing the shaft to the new level. Later on this "safety-back" can be cut out and the timbering completed. The practice at the Helen is to carry the shaft timbering with the work.

HOISTING.

An interesting feature in connection with sinking to a new level was developed at the Helen. The regulation cage has been used in the No. 1 shaft for the past six years. This cage is provided with tracks so as to receive the one yard cars used in development work and deliver to a double decked head frame at the collar of the shaft. The first deck is at the collar where tracks lead to the old pit into which the waste rock is dumped. The other deck

is above this at such a height that a trestle leads from it to a point over the railway track and high enough to permit dumping the car's load into one of the standard railway ore cars. This deck is used in case ore is cut in a new level before No. 2 shaft is completed. This upper deck is also used for loading merchantable pyrites. This material is sent up No. 1 shaft so as not to contaminate the iron ore or interfere with the latter's output.

When sinking is in progress a short chain is suspended from the centre of the bottom of the cage. To this chain the muck bucket is hooked, the chain being short enough to prevent the bucket swinging and catching the shaft timbers. By this arrangement, too, the cage is at all times available for the work for which it is intended.

The head frame over No. 1 shaft is of such a height that the cage may be raised till the bucket of muck clears the collar of the shaft by a few feet. A simple and easily operated device is used to receive the muck bucket after it has been raised to the surface. From the head frame to the edge of the worked out pit, there is an overhead track on 6″ x 10″ timber, supported by a series of brackets and standing some 10 feet above the ground. On this track runs a two wheeled carriage from which is suspended an angle frame and chain, a few feet in length, provided with a hook at the lower end.

When the bucket of muck is raised clear of the collar of the shaft, the hook of the carriage chain is hooked into the bail of the bucket. A signal is then given to lower the cage. The lowering of the cage throws the weight of the bucket from the cage to the carriage. The cage chain is then unhooked and the bucket pushed to the edge of the pit, a distance of about 30 feet, where it is dumped. This arrangement cuts out the use of a car and calls for only one dumping, instead of two as practiced with the old method of receiving a muck bucket.

The practice up to the present winter has been to raise all the ore as fast as broken in development and mining. The ore is raised in two skips, each of two tons capacity, acting in counterbalance. The skips, from a point 4′ above the collar of the shaft, follow an incline to the top of a No. 8 Gates gyratory crusher into which they dump directly. The ore, crushed to pass a two inch ring, passes directly from the crusher into hopper bottomed steel

cars of fifty tons capacity, standing on the railway tracks below. Between the closing and opening of navigation, side dump cars were substituted to permit of easy dumping on the stock pile ground.

During the present winter, the ore, instead of being raised to the surface is being stored underground. Ore taken out in development work on levels Nos. 3 and 4 will be dumped through openings into the levels below. Ore from the fifth level development work is raised to the fourth level where it is trammed and dumped into fifth level stopes and only ore won from development work is raised.

In order to handle this ore underground, it was necessary to somewhat modify the Kimberley skips in use. The lower half of the back of the skip facing the station, is hinged at its upper side and held in position by a hook fastened to the bottom of the skip. In the skip there is a false bottom sloping at an angle of 45 degrees to the lower side of the door. This skip has the regular capacity of one mine car and was made in the mine machine shop.

On the fourth level where the ore from the development work below is dumped, a spout is arranged to carry the ore from the skip to a mine car. This spout is so suspended, just outside the skip-way, that, if the lower end is not supported, the spout hangs in a vertical position clear of the skips. A few feet higher up in the shaft and near the centre of the sides are pivoted the arms of a skip chair, designed to support the skip when dumped. To the upper and shorter end of the chair arms is attached a chain by which the chair may be swung from a vertical position (on its points of support) so that the portion of the chair designed to support the skip strikes the wall of the shaft opposite the station. When the chair strikes the wall it is automatically locked out of the way of the skip. The spout and chair are so connected and arranged as to drop automatically into receiving position as the skip coming up passes them. After the skip has discharged its load, the skip is raised a few feet and the skip-tender throws a lever which sets the spout and chair into clear of the skip-way ready for the next up trip.

This arrangement does not interfere with using the skip in the ordinary way. That is, it may be sent with a load to the crusher on the surface if desired.

EXPLORATORY OPERATIONS.

During the past year opportunity was afforded for undertaking exploratory work, that had been contemplated for several years past. Quite the most interesting result of this work both geologically and economically, was the discovery of large bodies of pure pyrites to the east and high grade bessemer hematite to the west of the Helen deposit.

From drilling done in the early days of the mine beneath the waters of Boyer Lake, a pocket of pyritic sand was known to exist to the west of the present mine workings. This deposit, which has a thickness of 130 feet, is about 160 feet below the old lake level and is overlaid by 40 feet of mud.

To tap this deposit it was decided to drift westwards from the third level. The drift after crossing the clay dike penetrated a body of hard red hematite, that proved on analysis to be of high grade bessemer. An average analysis of this ore is as follows:—

Iron	60.00 %
Silica	9.70
Sulphur	.050
Phosphorus	.030

The main drift and crosscuts have shown this ore body to be elliptical in form with the greater axis striking east and west. A smaller parallel body of siliceous bessemer ore has been tapped 60 feet to the North. This siliceous ore runs:—

Iron	50.00 %
Silica	25.00
Sulphur	.070
Phosphorus	.035

The main drift has not yet reached the pyrites pocket.

On the fourth level drifting has been directed westward through the clay dike beneath the third level drift. Here, too, on passing through the dike the bessemer hematite ore was encountered and is now being blocked out. Drifts from the fifth and sixth levels are planned to reach this zone as early as possible.

While the ore body as worked out on each level has tapered to the east, this was not caused by a converging of the walls (so

far as is known) but by a gradual change from merchantable into low grade pyritic material. The extension of the iron formation eastward is apparent on the surface, over the summit of Mount Hematite, and an angle drill hole put down near the crest of the ore body in an easterly direction, showed a good deal of siderite ore for some 300 feet or so.

With the object of exploring this ground to the east, the main drift on the fifth level was continued under the mountain beyond the boundary of merchantable ore. Thirty feet of drifting brought the breast of the drift into clean hard pyrites. On February 15th the main drift had progressed 160 feet through this class of material. Crosscutting at the usual angle of fifty degrees is in progress and continues to show that a very large deposit of high grade pyrites has been encountered. Raises are being put up in this deposit so that it may be ready for stoping on the opening of navigation 1910.

This pyrites appears to carry but little waste matter and is quite uniform in character. Analyses show 49% for sulphur and only a trace of arsenic. A 45% merchantable ore should be easily secured. The pyrites is rather friable and breaks up rather easily, so that it may be crushed to "fines" at small expense and thus answer the demand for both "lump" ore and "fines."

GRADES OF ORE MARKETTED.

Up to the present only one grade of ore has been shipped from the Helen. The contracts have been on the basis of those for Old Range Non-Bessemer ores, which in 1909 called for Iron, natural 55%. Contracts filled have specified a sulphur content not exceeding .150%.

During the coming season three grades of ore will be shipped. These are Helen No. 1 with a guaranteed analysis of natural Fe-56%, Sulphur .15. Helen No. 2 with a guaranteed analysis of natural Fe-56%, sulphur .50 and bessemer with a guaranteed analysis standard.

In addition to the iron ore contracted for, there is also the pyrites output and arrangements are being made for mining 50,000 tons of this material for 1910 delivery.

OUTPUT.

Shipments from the Helen date back from 1900. In the earlier years a large proportion of the output went to American buyers. Since 1904 the buyers have been M. A. Hanna & Company of Cleveland, Ohio, the Hamilton Steel & Iron Company, Canada Iron Furnace Company and the Algoma Steel Company. In 1910 the entire output, excepting the pyrites will be sold to the Algoma Steel Company.

The production to the close of 1903 amounted to 803,160 tons. Since then, shipments have been as follows:

1904	118,354	tons
1905	169,526	"
1906	121,550	"
1907	142,832	"
1908	148,420	"
1909	170,065	"
Grand Total	1,673,915	tons

In addition some 6,800 tons of pyrites "fines" has been shipped.

GENERAL EQUIPMENT.

Until 1909, steam, generated by a battery of five boilers having a capacity of 700 horse-power, was utilized for operating the mine plant. Last year, the plant was entirely electrified. Power is supplied by the Algoma Power Company from their plant at Michipicoten Falls, some ten miles distant. This power is used for operating a twenty drill compressor, hoists for both No. 1 and No. 2 shafts, crusher and machine shop engine, and all surface and underground pumps.

The pumps used under-ground are four-stage direct drive McDougall pumps. These electric pumps are capable of removing the mine water, which is equivalent to 300 to 500 gallons per minute. The pumps used on the surface are single stage, but otherwise are the same as those installed underground.

The mine is provided with well equipped machine and blacksmith shops, while the camp buildings include office, laboratory,

school, general store, sleep camps to accommodate 300 men, hospital, cook camp, assembly hall, pool room and fifteen cottages for families. These and the stations at the various working levels in the mine are lighted by electricity.

The principal levels in the mine are connected by telephone, with operating building on the surface.

The water supply is derived from a lake 250′ above the railway track. From the lake the water is pumped to a 100,000 gallon water-tower, from which water mains are laid to the camp buildings, boiler house, dry-house, etc.

DISCUSSION.

PROF. COLEMAN:—I have followed with great interest the development of the Helen Mine. I think few of us had any expectation that the deposit would have attained the depth that it has; or that so great a tonnage of ore of fair grade would have mined from it. The mine has one feature that is of special interest to mining geologists. It is the only great iron mine of Keewatin age in North America that has been derived almost wholly from oxidation of sulphide material. All others are supposedly derived from carbonates or else belong to some other variety of iron formation; and the fact that large masses of high grade pyrites have been found in this mine is of singular interest to us all.

MR. A. B. WILLMOTT:—Mr. Seelye, in his description of Helen Mine, has considered the subject from an altogether different standpoint from that on which the earlier papers by Dr. Coleman and myself were based. We discussed merely the geological aspects. To those interested in the exploitation of an iron deposit, the modern workings of the Helen Mine will, I am sure, prove of great interest. The various mechanical features used for extracting the ore have been vastly improved during the last few years, and costs have been reduced.

The Helen Iron deposit is the largest iron body exploited in Canada. The paper is of particular interest to me, since it fell to my lot to predict what would be found beneath the surface, and in

several very important respects, those predictions have proven correct.

I fancy I could get up an interesting argument with my friend Doctor Coleman on the origin of this particular ore body, and especially on the point whether it came from the carbonate or from the pyrites. The question is surprisingly involved, and it is a question whether the carbonate rather than the pyrites, did not contribute more to the formation of the hematite. From the fact that the pyrites exists unaltered in such large quantities, we may infer that it was the carbonate that was oxidized in making the hematite. It is an interesting fact that hematite is also being found on the west side of the dyke that crosses the ore body, and which dyke was overlooked in the very early stages of the development of this ore body. The reason for this is that it was covered by the waters of the lake. This dyke which cuts the ordinary Keewatin iron bands, had a wonderful influence in forming this deposit. One of the important things that we can learn from the Helen ore body, in connection with the study of other Ontario formations of Keewatin age, is that in those localities where dykes have crossed and given facilities for entrapping waters, we are then likely to find iron ore deposits.

PROGRESS IN ELECTRO-SIDERURGY.

By P. McN. BENNIE, Niagara Falls, N.Y.

(Annual Meeting, Toronto, 1910).

Much has recently been heard concerning "The Conservation of Natural Resources." Hence it may not be inappropriate at this time to refer briefly to that phase of the question relating to the use of electrical energy in the production of iron and steel.

The natural resources of any country may be broadly divided into two classes: those that are exhaustible and those which are replenishable. In Canada there are certain reposited resources, such as forest reserves and Crown Lands, while a certain control is exercised over mineral deposits. It may be said that indiscriminate development or utilization of any country's resources generally means more or less waste; and though it may appear to some that such a policy of reserving resources lessens present-day opportunity, the real effect is to prolong the opportunities of a country or section over a greater period of time, thus ultimately conferring a greater benefit to the people.

There are certain classes of natural resources that must be viewed as distinctly exhaustible. Among these may be placed most of the natural fuels, such as coal, oil and gas, since their replacement must extend over a geologic period of time, too long to be considered in the economic life of a nation. There is, however, a class of fuels that, with equal distinctness, belong to the replenishable resources of a country. Among these may be placed wood-fuel, charcoal and any heat energy derived from hydro-electric installation. Coal once used is practically gone for ever; whereas wood or charcoal may in a few years time be replaced by further growth. Water powers on the other hand when properly guarded from well recognized detrimental influ-

ences, such as unwise or ruthless destruction of forests within their drainage areas, constantly renew themselves by a natural process. Therefore, obviously the best method of preserving natural resources is to conserve those that may be used but once and utilize as far as possible those that are replenishable. To the former class belong most of the natural fuels and to the latter belong water powers and forests.

ELECTRO-SIDERURGY.

The industry of iron and steel production and manufacture bears such an important share in the economics of this continent that it cannot be considered a digression to point out that electro-siderurgy will fulfil a high mission in so far as it contributes to a real saving in the resources of the commonwealth. Of course it will be understood that where electric energy is developed by coal, oil or gas in the ordinary manner, it does not represent the same order of economy as when generated by hydro-electric installation or the utilization of otherwise wasted gases. This paper is intended to be a résumé of recent progress with electric furnaces in the production of iron and steel, thus in a measure filling a gap between the date of the publication of the Canadian Government reports and the present time.

To take up first the production of pig iron by means of electric furnaces as representing the first step in a long series of manufacturing operations, the practical work thus far appears to be confined to two installations that are curiously alike in their general scheme. One of these plants is at the Domnarfvet works in Sweden where a furnace, designed by Messrs. Gronwall, Lindblad & Stalhane, is in use. This installation has been described in a pamphlet compiled by Dr. Haanel and issued by the Dominion Government.

Very little data is yet available as to the actual operation of the Swedish plant, although there can be no question in view of results obtained elsewhere of the ability of the furnace to produce a satisfactory grade of pig iron. The other installation is located at Héroult, Shasta Co., California, where the Noble Electric Steel Company has put down a complete plant, including equipment for mining and handling iron ore and limestone, a

complete by-product recovery charcoal plant and a large electric furnace, the power for which is supplied from the generating stations of the Northern California Power Co.

In consequence of its situation at a considerable distance from the source of necessary supplies, such as electrodes, electrical machinery, refractories, etc., some delays have been experienced in the construction and operation of this plant. However, on December 14, 1909, actual furnace operations were commenced and continued until the supply of 16 electrodes then in stock was exhausted. During this period the furnace produced about 20 tons of high grade pig iron per diem. We are informed by Mr. Lyon, manager of the plant, that the production during the whole period averaged one ton for 0.22 horse-power year. This may be considered as a very satisfactory result under the circumstances. The resumption of operations is now merely delayed pending the arrival of a large consignment of electrodes.

In the case of pig iron production by means of electric furnaces the item of cost for carbon becomes of less moment than with ordinary blast furnaces, as in the electrically-heated apparatus only about one-third the quantity is required. Therefore, where cheap electric power and iron ore are available an electric furnace plant can afford to pay more for coke or charcoal than the blast furnace.

The local conditions at the California plant are particularly good. The furnace plant is located on the Pitt River with reference to the contiguity of iron ore and limestone. Immediately to the rear of the furnace building is a mountain, the height of which is about 1,800 feet. At its summit is a large deposit of high grade magnetite, averaging 68 per cent. iron and very low in sulphur and phosphorus. In contact with the iron ore is a body of calcite of very good quality. The two adjoining deposits are shown in illustration (Fig. 1). The method of assembling these two important items, therefore, becomes very simple. For some time to come all the iron ore the furnaces can use will be produced from an open quarry. The materials are conveyed by surface tramway to a point on the face of the mountain above the furnace buildings; there crushed by motor-driven appliances, then dropped by gravity tram into bins adjacent to the electric furnace. The iron ore can be laid down at $1.50 the ton, while the supply of lime should not cost over 50 cents the ton.

For reducing carbon, charcoal will be used. The installation includes a complete by-product recovery charcoal plant, the supply of wood for which is supplied by local lumber companies at a figure that should permit of $9.00 charcoal. Electric power being supplied by the Northern California Power Co., an affiliated concern, the actual price charged for power is a matter of mutual agreement, but about $15.00 the horse-power year is an approximate figure. The charcoal consumption should be in the neighborhood of one-third ton per ton of pig produced. Such a plant should produce a very high grade iron at a cost of between $15.00 and $16.00 the ton.

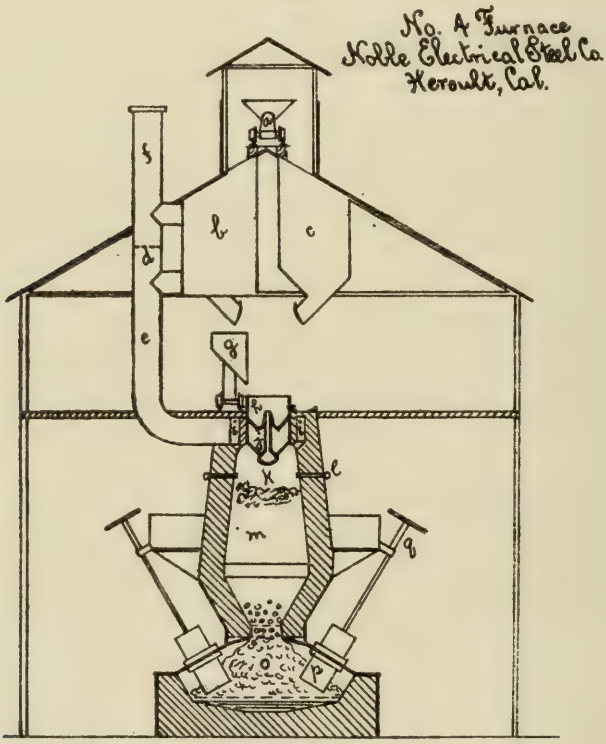
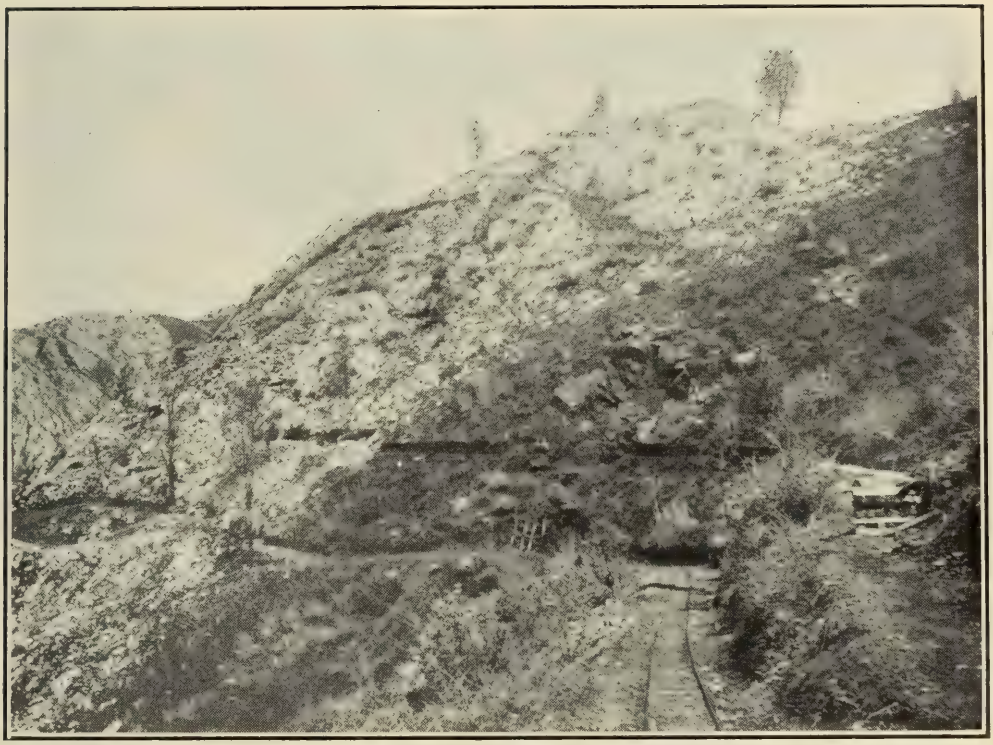
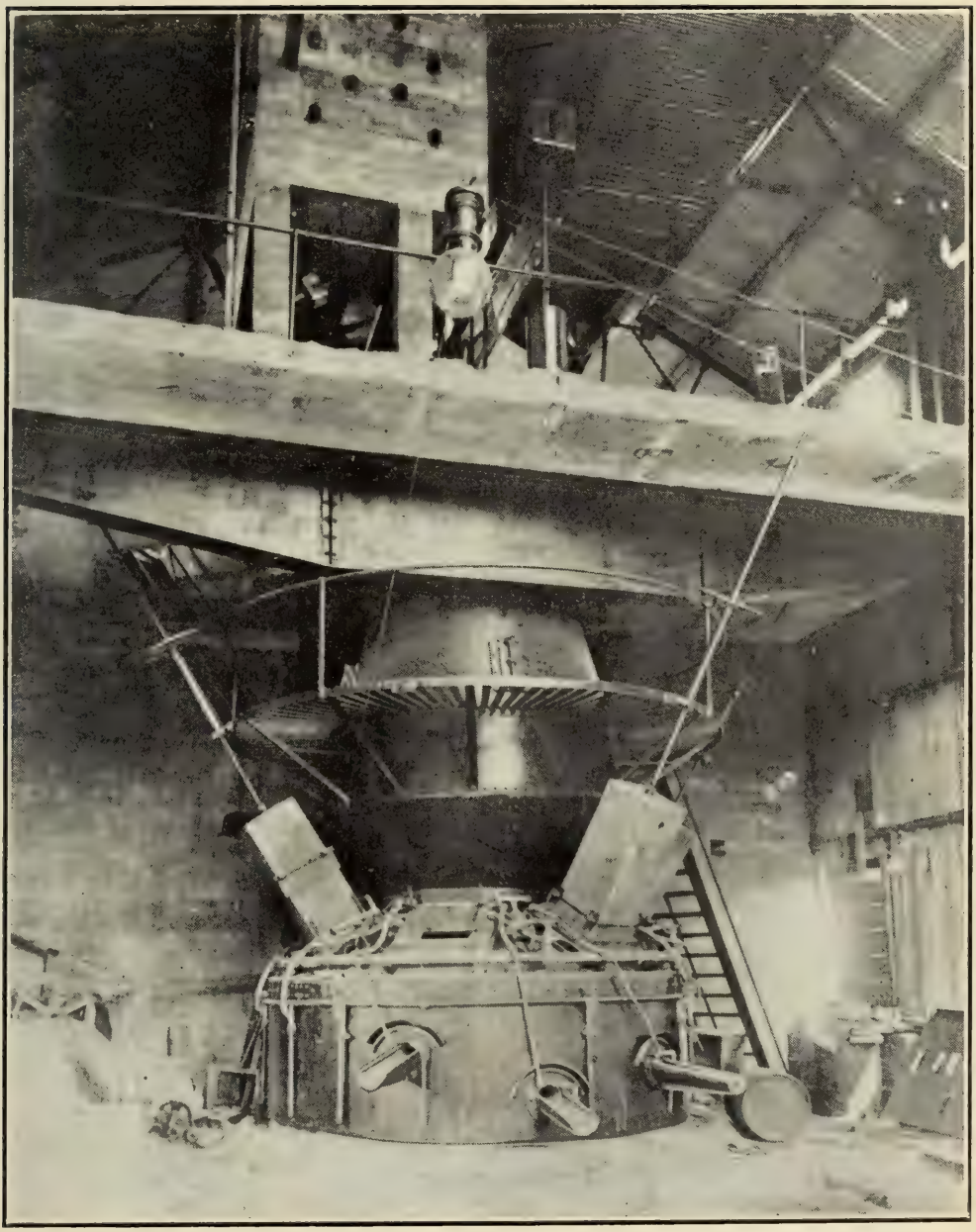


Fig. 3.

The furnace itself (shown in illustration Fig. 2) is designed to have a daily capacity of 20 to 25 tons of pig iron. Electrically it is designed for a maximum load of 1,500 kilowatts, 3-phase



View of iron ore and limestone deposits at Heroult, California.



Electric Pig Iron Furnace.

current at 60 cycles, 100 volts, being supplied from three 750 k.w. transformers. There are six electrodes employed, two on each phase. Three of these electrodes may be seen in position in the illustration, the furnace not being completed at the time the photograph was taken. Three tap holes have been provided at different levels, so that if necessary the crucible of the furnace may be partially or completely emptied.

The California furnace is shown in sectional elevation in illustration (Fig. 3). The base of the furnace is composed of a steel shell lined with suitable refractory materials, forming a circular crucible. Above the crucible thus formed is a superposed stack, somewhat resembling a small blast furnace in shape, and having a bosh communicating with the crucible.

The method of working is as follows: The charge, consisting of iron ore, mixed with its proper proportion of fluxing materials, is fed into a pre-heating chamber (*b*) wherein these constituents are dried and heated by means of gases from the chamber (*k*) at the top of the stack. The gases pass by the flue (*e*) to the heating chamber (*b*) and out by flue (*f*). A damper (*d*) permits of direct passage to atmosphere when desired.

Carbon, in the form of charcoal, is contained in hopper (*c*) and fed alternately with the iron ore and lime mixture, by means of scale car (*g*) running on a circular track around the double-bell hopper (*h*).

That a very good grade of pig iron is produced may be seen from the following analyses of product:—

	1	2	3	4
Silicon.	0.94	0.84	0.98	0.94
Sulphur.	0.042	0.037	0.049	0.002
Phosphorus.	0.027	0.022	0.03	0.02
Manganese.	0.11	0.03	0.08	trace
Combined Carbon. .	1.20			
Graphite Carbon. . .	2.06		4.56	3.25

These figures indicate an iron of exceptional quality, but the high purity of the ores used should be considered. However, owing to the peculiar conditions of its production, it may well be that electric furnace pig iron will create a special market for itself.

California foundries using the Noble Company's product are extremely well pleased with it.

There is hardly any doubt that equally good conditions exist in several places in Canada where suitable raw materials, such as iron ore, limestone and the necessary carbon for reduction, either charcoal or prepared peat, can be cheaply assembled at a point to which electric energy can also be delivered at a low rate. Without wishing to be prophetic, it is not too much to say that this year should see the beginning of similar installations within the borders of the Dominion.

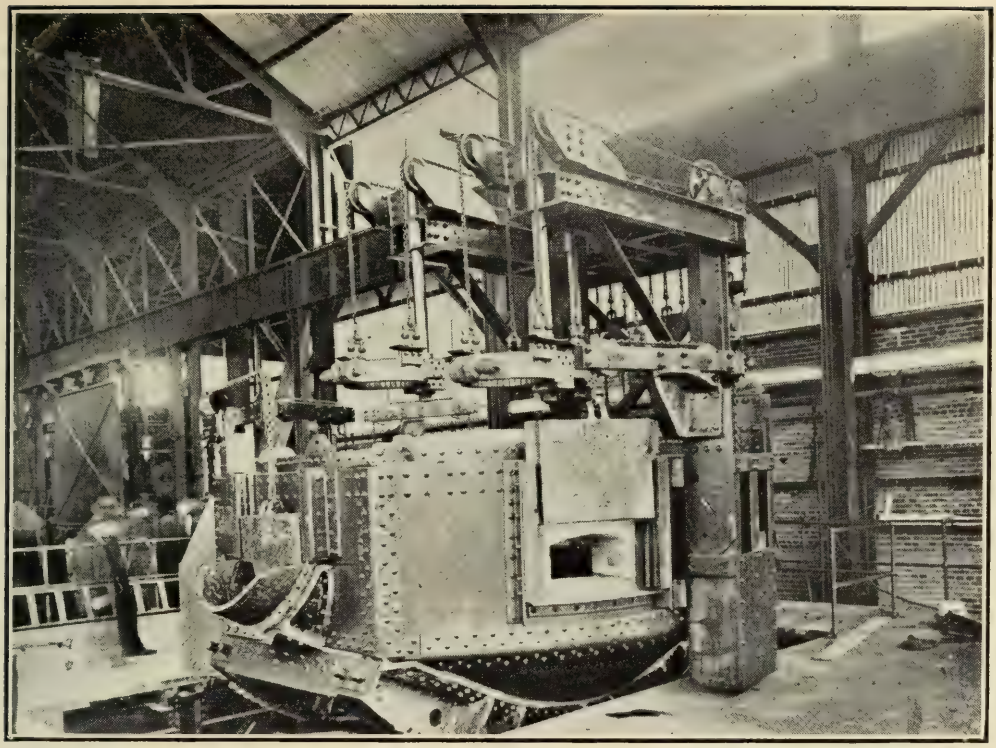
When it comes to the manufacture or treatment of steel by means of the electric furnace it is gratifying to report very substantial progress, both from the point of view of a rapidly increasing tonnage, and the creation of a practically new metallurgy. So far as tonnage is concerned it has two phases, first the increase due to a multiplication of installations of electric furnaces, and second, a greatly increased tonnage capacity in the units themselves. At the present time the following installations are claimed for various types of furnaces:—

Stassano	12
Keller	4
Héroult	20
Girod	18
Rochling-Rödenhauser	12

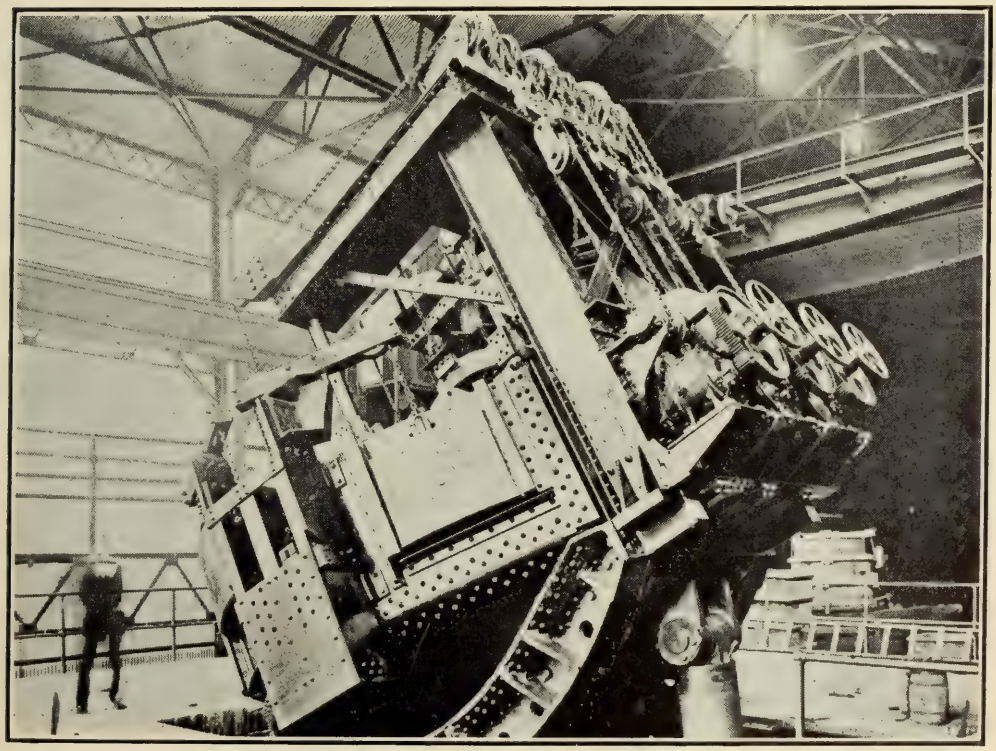
a total of 66 furnaces producing steel.

The largest of these furnaces in ton capacity per charge, are those of the Héroult type, as the furnace will easily handle a charge of 15 tons. Moreover, as the furnace at South Chicago is (Fig. 4 and 5) being used for refining and finishing Bessemer metal charged liquid, and is able to accomplish this in a period of from one hour to one hour and a-half, the daily capacity with the furnace working well, is from 150 to 180 tons. At the Worcester (Mass.) works of the American Steel & Wire Co., a similar furnace is installed, which will, however, be charged with liquid open-hearth metal to be subjected to electric furnace refining, the product to be used for special wire purposes.

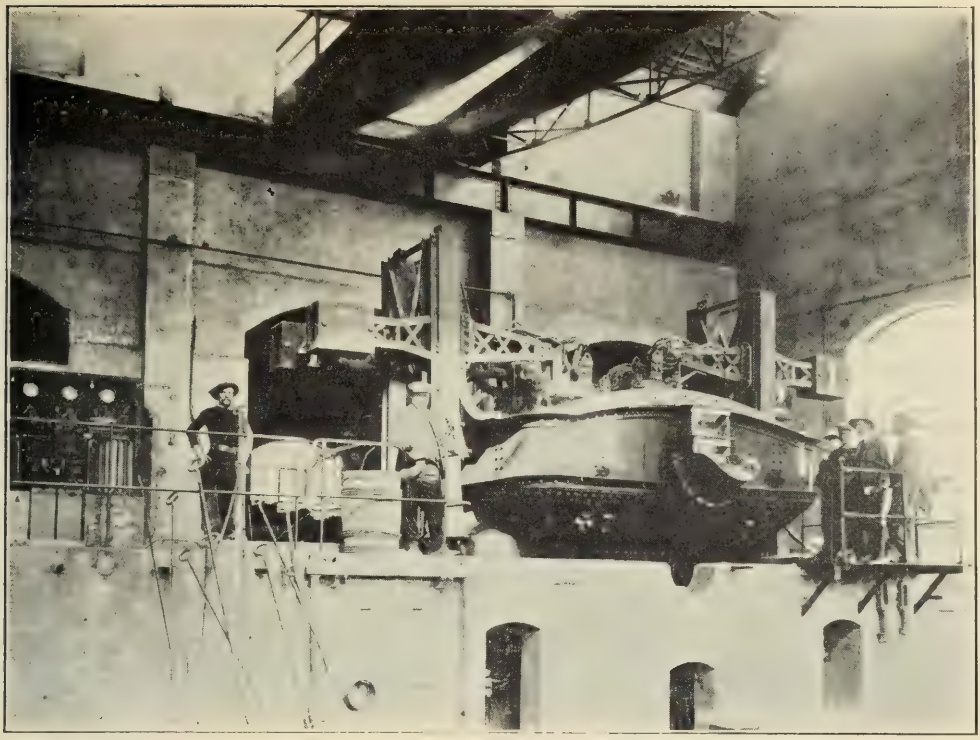
Girod has installed at Ugine, France, a most complete electrically equipped steel works, the entire plant being operated



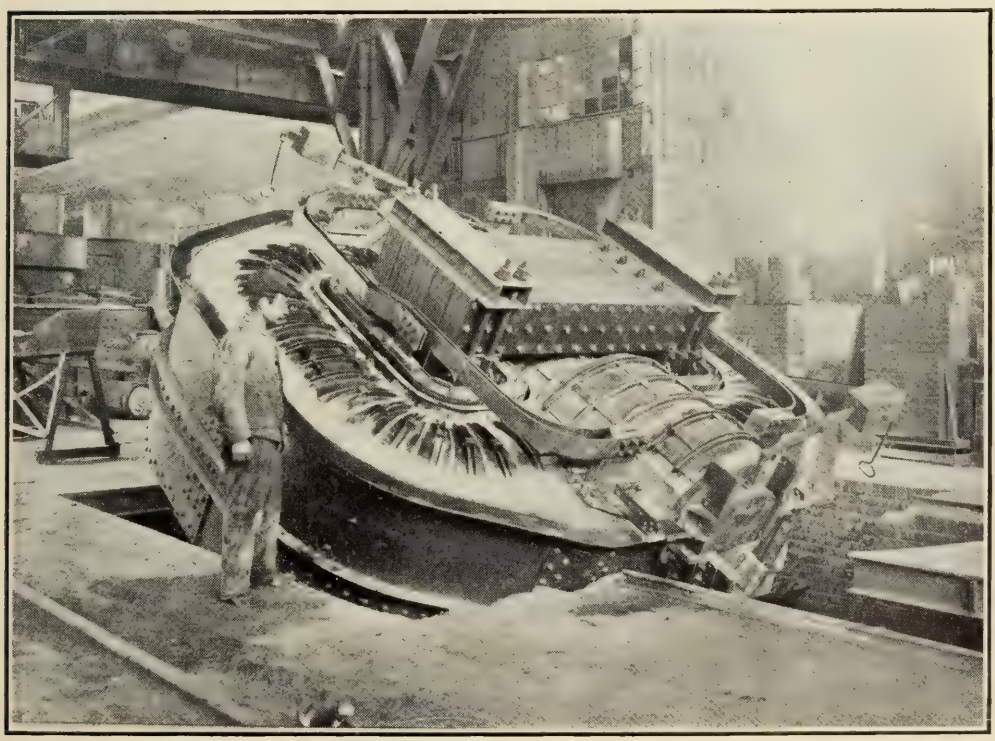
Heroult furnace at South Chicago.



Heroult furnace tilted.



12-Ton Girod Furnace at Ugine, France.



Single-phase furnace. Röchling Rodenhauser type. 8 tons capacity.
In tilted position.

electrically, and being unique in that there is not a steam boiler (Fig. 6) in the entire works. There are two furnaces of 12½ tons (nominal) capacity each, so that the Girod furnace, in point of tonnage, is running a close second to the Héroult type.

The Rochling-Rödenhauser interests have been operating an eight (Fig. 7 and 8) ton furnace for sometime. Thus a very substantial tonnage is now being drawn from electric furnaces, as the above figures refer to capacity per charge, and heats are being run off in from one hour and a-half to two hours. The above does not take account of a number of furnaces utilized entirely in the production of tool steel.

The year 1909 will mark the first appearance of electric furnace (Fig. 9 and 10) steel in quantity in the statistics of the American Continent. While there are as yet no electric steel furnaces installed in Canada, the steel companies are following outside progress with keen interest. The magnificent metallurgical results attained indicate that substantial amelioration in quality would result from electric furnace treatment of their molten steel, at an expense more than justified by the improvement.

It would, perhaps, be of interest to refer to the technical progress made in furnace design, operation and metallurgical practice. Electric furnaces have created problems of their own, and by reason of the widely different types being developed, problems have arisen peculiar to each type. In ordinary steel furnaces the temperatures reached are generally limited by the refractories, so that in electrical furnaces, by reason of somewhat higher temperatures, the matter of suitable refractories at once becomes of prime importance. It is gratifying to report, therefore, that with reference to this problem progress has been made. Carefully chosen refractory materials, with improved methods of application, has resulted in prolonged life, with a consequent reduction in the item of refractories cost. All electric furnaces are basic-lined, and it has become almost standard practice to use a proportion of tar or pitch as a component of the lining mixture. When this is baked in properly a good bottom is assured.

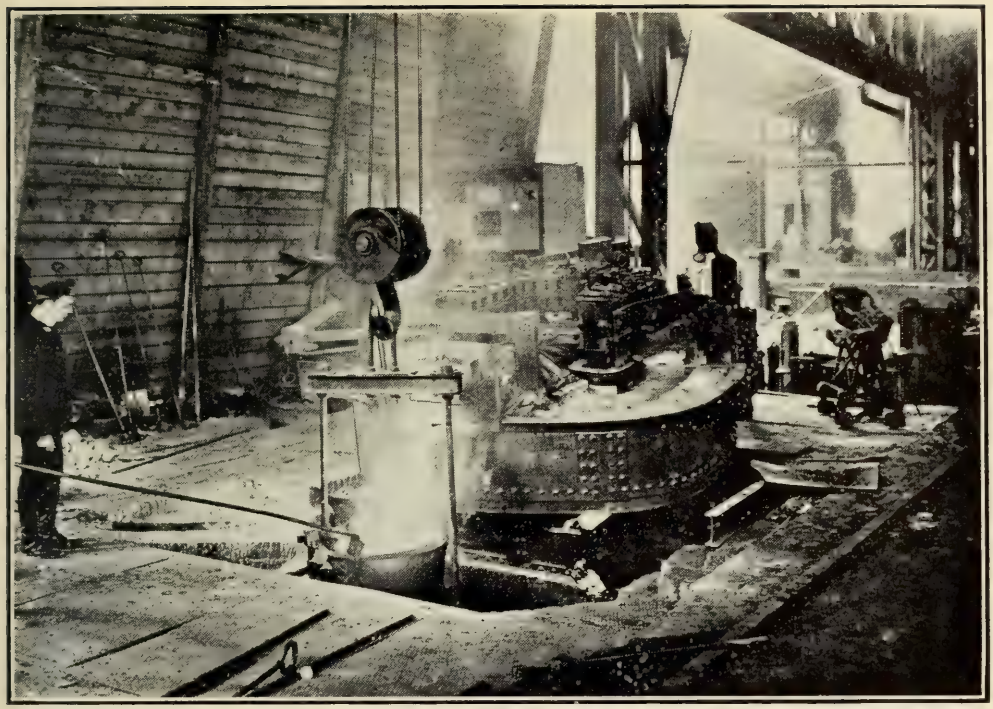
The cost of electric power still remains of considerable moment where melting from the cold state is carried on. It should be borne in mind that heat energy electrically developed is not "cheap" energy, when compared with heat energy developed by

combustion of fuel. This is especially true where electric power is steam generated, that being a roundabout way of using the calorific energy of fuel. Its advantage lies, however, in the tractability of electric power, the ease with which it may be controlled, the temperatures of the metallic bath regulated, the high temperature attainable and metallurgical conditions possible with electric furnaces. Even though more costly, these peculiar qualities of electrical energy favour its more efficient use. When, however, it comes to treatment of molten steel, as an operation secondary to Bessemer or open hearth treatment, the electric energy is being used under extremely favourable conditions, for it is found with the larger furnaces that a power consumption of 100 to 150 k.w. hours per ton suffices. Where 50 to 75 tons per horse-power year can be thus treated, this item becomes of minor importance.

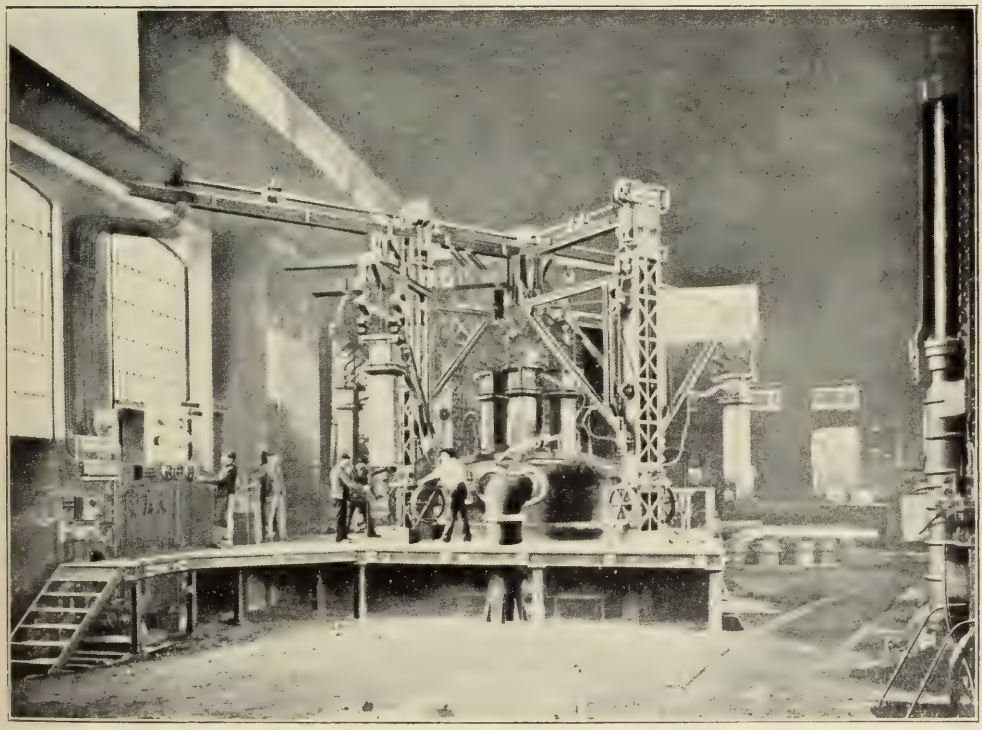
To those conversant with the facts, the greatest significance attaches to the metallurgical progress being made. Electric steel furnaces present new metallurgical conditions to the steel maker, with the result that a new metallurgical practice is being developed.

Hypothesis and theory are following hard upon observed results with electric furnaces. These results are throwing light upon phenomena that may occur under certain conditions; hence practical steel makers would do well to pay close attention thereto, as possibly indicating interesting experiments with existing apparatus, particularly the open-hearth furnace.

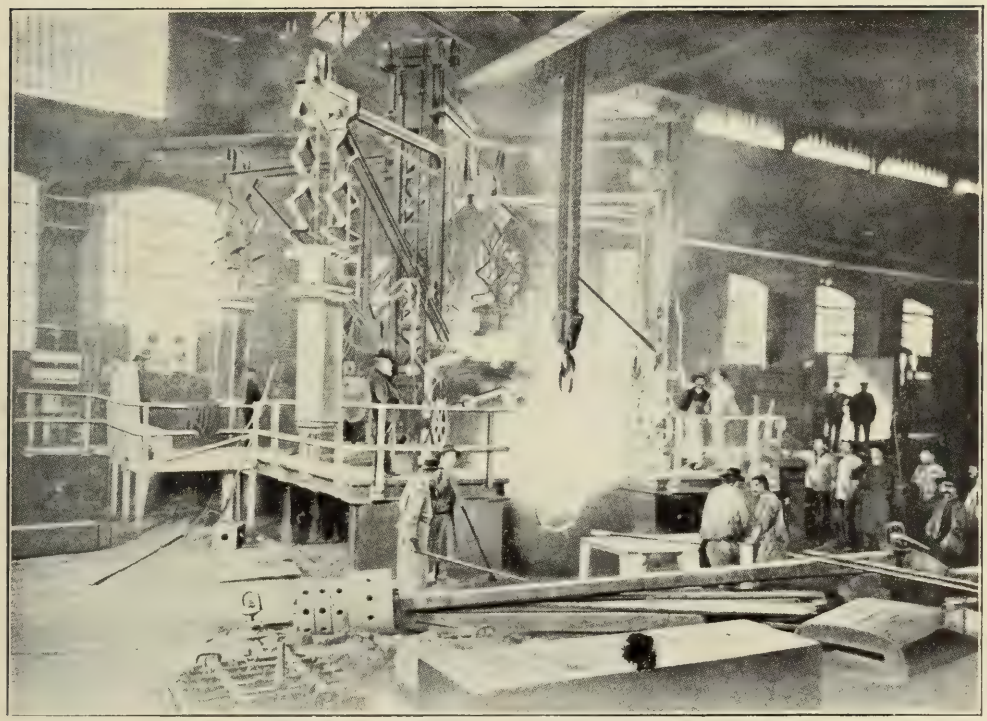
It has been meanwhile conceded that, with reference to elimination of oxides, sulphur and phosphorus, the electric furnace is capable of rapidly removing these deleterous impurities to an almost unprecedented degree. Certain it is that no matter why, the electric furnace is an efficient remover of certain materials regarded as being undesirable in steel. This is one striking characteristic of the new metallurgy-improvement in quality by *removal* of impurities rather than merely rendering them supposedly innocuous by metallurgical nostrums. F. W. Harboard has written an interesting paper on "*The Electric Refining of Steel,*" with particular reference to the reactions supposed to occur under electric furnace conditions, resulting in the elimination to a high degree of such impurities as oxides, sulphur and



Tapping steel from three-phase induction furnace.



Keller Electric Steel Furnace at Unieux, France.



Tapping steel from Keller furnace.

phosphorus. It is a fact, however, that nothing is specifically done in electric furnace treatment towards the removal of nitrogen, an element to which recently metallurgists have been directing attention. As titanium readily forms a nitride, the resulting compound entering supernatant slags, a small addition of ferro-titanium would probably be justified by results.

Reference has been made to the development of a new metallurgy connected with electric steel furnace practice. It was to be expected that new conditions would be productive of new methods. Electric furnaces differ from Bessemer or open-hearth furnaces in that the atmosphere above the bath is under greater control. It is well understood that the older metallurgical processes, Bessemer and open-hearth, actually depend upon oxidising conditions for their results, and their metallurgy is based upon the chemistry of oxidised compounds. Instead of being forced to work under such conditions, with the electric furnace we can work under non-oxidising conditions, either neutral or actually reducing.

Now to what extent has this modified the metallurgical results? First, in our ability to completely remove oxides, or oxidising gases; Second, it has been shown that by means of electric furnace treatment of liquid metal the sulphur and phosphorus may be eliminated to a hitherto unprecedented degree. Sulphur in steel is chemically combined with iron and manganese. In basic furnaces these sulphur compounds will pass into the slags in proportion to the temperature, and the basicity of such slags. But as these sulphur compounds are also soluble in the steel their complete removal cannot occur, but only in proportion to their respective solubilities. In the electric furnace, conditions permit the formation of calcium sulphide, CaS, and this *calcium* compound, as distinguished from *iron* or *manganese* sulphide, is not soluble in the bath, hence its removal is easily possible.

Phosphorus is removed in basic furnaces in the presence of an oxidising atmosphere as phosphate, an oxygen-containing compound. In the electric furnace, by use of some ground carbon, coke for instance, the phosphate may, by reason of the reducing or neutral atmosphere possible, be converted to calcium phosphide. Once in that state and with the atmosphere maintained, it remains in the slag. Hence it is easy to see from the

observations made at the very beginning of electric furnace steel refining, the birth of a new metallurgy that may even go so far as to modify in some degree the present-day practice of the older processes.

As to the physical results obtained with steel produced in the electric furnace, but scant information has been published, except by those interested in the exploitation of some particular type of furnace. From an independent source, however, we learn that steel rails, to ascertain what physical characteristics they possess, have been made from numerous heats, with surprising and gratifying results, the rails, exhibiting extreme toughness, resistance to shock, and qualities superior to ordinary rails of similar carbon content. Dr. Héroult has said that for similar analyses the electric furnace product shows approximately 20 per cent. higher tensile strength and elongation than the product of ordinary methods.

Aside from rail and structural steels there is another important line in which the electric furnace product is receiving recognition, the use of such metal for steel castings. Several electric furnace steel plants in Europe have been installed especially for the production of steel castings. It is claimed that aside from the superior quality of the castings, there is a large saving in respect of defective castings, these advantages more than counter-balancing the increased cost. Several important installations for this purpose have already been determined upon in the United States.

Finally, an important feature of electric furnace progress will be found in the relief held out to existing plants, particularly Bessemer plants. Operators of these by reason of changes in character of available raw materials, have been obliged to consider some sort of duplex process or abandoning the Bessemer in favour of open-hearth furnaces. The electric furnace is almost certain to find a large use as one unit in duplex processes, either as Bessemer-electric or open-hearth-electric.

DISCUSSION.

MR. J. C. MURRAY:—I would like to ask Mr. Bennie what materials are used as lining for the electrical furnace?

MR. BENNIE:—Magnesite is used—thoroughly calcined magnesite, mixed with tar. It is also possible to electrically calcine the magnesite and thoroughly shrink it before putting it in. We have made linings in that way, and we have found that the tendency to reform carbonate of magnesia is a function of the temperature to which it has been submitted, and with electrically fused magnesia that is thoroughly calcined, the rate of taking up the carbon dioxide is very much reduced. This naturally prolongs the life of the exposed portion of the magnesite.

We have also used bauxite and dolomite. Any of these will make a good lining, but the fact that the metal is at a higher temperature seems to be of some benefit—at least to the part not exposed to the air, that is the part under the bath.

MR. MURRAY:—You referred to artificial linings. In what shape would they be prepared?

MR. BENNIE:—Well, the preparation generally consists in heating the material up in an electric furnace to a temperature to which it will be submitted in the steel furnace.

MR. MURRAY:—You also referred to an electrical product that could be used as a lining.

MR. BENNIE:—Well, that is what I mean. That is simply taking an ordinary material, submitting it to electrical furnace treatment, and fusing it or sintering it. That is an artificial product in the sense that it is not used in the ordinary metallurgical processes in that condition.

MR. DENIS:—I would like to ask Mr. Bennie where he obtains the magnesite for his lining.

MR. BENNIE:—We have used the ordinary Styrian magnesite, Grecian or Indian magnesite, and some California magnesite; but if you are going to submit it to an electric furnace temperature I consider that the white magnesite is preferable to the ordinary brown magnesite.

MR. DENIS:—May I enquire if Mr. Bennie has tested any of the Quebec magnesite?

MR. BENNIE:—Yes, we have actually electrically fused some of the Quebec magnesite and made linings of it, and it does very well.

MR. DAVIES:—What is the consumption of charcoal per ton of pig iron?

MR. BENNIE:—About 700 pounds will cover it.

MR. OBALSKI:—I understand that you may reduce any class of iron ore in your electrical furnace, but I would like to ask in what form you use it, and whether you use it in a granulated form or not?

MR. BENNIE:—Yes, the only form I am familiar with is that used in California—that is in a solid lumpy condition. We do not use concentrates at all, but good hard lumpy ore.

MR. OBALSKI:—Have you experimented with the magnetic sands from the north shore of the St. Lawrence?

MR. BENNIE:—Not in an electrical pig iron furnace, but in smaller furnaces we have; though, I fear, that with the amount of material in the furnace and the height of the stack, and the fact that you have no blast, there would be trouble, and you might find most of the gas coming out around the electrodes rather than by the stack. This would preclude the use of material of that description.

PROF. STANSFIELD:—I have listened with much appreciation to Mr. Bennie's paper and consider that we are much indebted to him. There are one or two points, however, on which I should like further information. One point is with regard to the amount of horse power used for smelting iron ores in California. Mr. Bennie mentions 0.22 horse power year per ton of pig. Did that refer to the long ton or to the short ton?

MR. BENNIE:—I understand it refers to the long ton of 2,240 pounds.

PROF. STANSFIELD:—The matter of electrodes I believe is a very important one, and I understand from Professor Lyon that they have even got so far as to try graphite electrodes.

MR. BENNIE:—That is what they used entirely during the last run.

PROF. STANSFIELD:—Do you consider that the graphitized electrodes are as economically used or even more so than the carbon electrodes?

MR. BENNIE:—It is extremely doubtful. They cost more than twice as much, while experience with steel furnaces has been that even with a heavy breakage of amorphous carbon electrodes, the electrode cost per ton of steel is but two-thirds as much as when using graphite electrodes, which do not break.

The 24 inch electrodes that broke in the furnace were replaced by 17 inch, and finally by 20 inch round. At the time these 24 inch electrodes were made, trouble was being experienced with 16 and 17 inch electrodes made concurrently, and used in the manufacture of ferro-silicon. This was probably due to some error in the process of manufacture; for immediately following this period, there was only one or two broken electrodes during a period of several months. Some larger electrodes made during this latter period are to be tried in the steel furnaces, and if they do as well as others made at the same time have done in the ferro-silicon furnace, there should be a still further reduction in the electrode cost for making steel.

So far as concerns the use of similar electrodes in California, I might say that the first equipment consisted of amorphous carbon electrodes $18\frac{3}{4}$ inches square, 72 inches long, and that these broke in use. These electrodes were built up of smaller sections. Others made in this country and Sweden were tried, with unsatisfactory results, so that the operators were finally driven to use graphitized electrodes. Some of the later electrodes which have given good result in ferro-silicon and steel furnaces are to be tried in the pig iron furnace. We believe there is no reason why, when having once accomplished the art of making these large amorphous carbon electrodes, their quality should not be maintained.

PROF. STANSFIELD:—Can you give us some general idea of the relative advantages of the Héroult furnace and the Girod furnace? I suppose that the advantage of the Girod furnace is that there is only one electrode to be manipulated; while I presume these metal electrodes in the base of the furnace might lead to considerable heat losses.

MR. BENNIE:—So far as the difficulties of regulating the electrodes are concerned, you can regulate the voltage drop with nicety whether you are using one or two or more electrodes. You can take a three-phase Héroult furnace where they are connected up without the neutral at all, and each electrode is regulated independently.

As far as the Girod furnace is concerned, when using four electrodes, you must regulate for a difference in resistivity at the bottom of each electrode, and you can do it just as well with one as with the other. There certainly must be a loss of heat through the metallic conductor in the bottom. They use a water cooling arrangement on the outside, and all the heat absorbed by that water is at the expense of the power bill.

A MEMBER:—I would like to ask if the electric treatment of magnesite is cheaper than that produced by the roasting process?

MR. BENNIE:—No, sir, it is not.

A MEMBER:—What is the difference in cost?

MR. BENNIE:—That comes in in connection with the operation of driving off the carbon dioxide, taking magnesium carbonate, and producing the magnesia of commerce. I should say you could do that much more cheaply with gas. Anything requiring a low temperature obtainable by gas, had preferably be undertaken with gas; but if you wish to operate at higher temperatures, it is cheaper to employ electrical heating. The electrically calcined magnesia has been submitted to probably 1,700° centigrade. We have even used the combined method of heating up to a certain point with gas, and then applying the electric current.

A MEMBER:—Can you tell us what the energy in California costs—how much per horse power?

MR. BENNIE:—If Prof. Lyon were here he might be able to answer that question, but as the Northern California Power Company and the Noble Electric Steel Company, are practically one company, one being the right hand and the other the left hand—it is whatever they like to make it. I might hazard a guess that the Power Company would not be treating them well if they charged more than $15.00 the horse power year.

MR. O. N. SCOTT:—May I enquire if the temperature in the electric furnaces can be regulated?

MR. BENNIE:—I would answer yes and no. As far as the induction furnace is concerned, in which the heat is generated directly in the metal, you can regulate the temperature to a nicety and hold it at any particular point as we have done in one furnace we constructed. You can actually measure the efficiency of the

furnace by means of meters, holding the bath within a few degrees and measuring how much electric energy you are putting in it. You could also tell what was the amount of energy you were radiating. However, when it comes to the furnace of the Héroult type, in which the heat is generated at the base of one or two electrodes, as an open arc, or in the slag, it is more difficult to regulate the temperature. You can only do it by the amount of energy put in, but you necessarily have at the bottom of each electrode a zone of very high temperature; because all the heat which is absorbed in the bath or the slag, is generated at one point, and from there conveyed into the metal or into the slag or radiated into the other portions of the furnace.

The same is true of furnaces of the Girod type. The energy input can be regulated with some degree of certainty. The arc is formed between the electrodes and the bath, the heat energy being either absorbed by the bath, or radiated. There is no advantage in using electrical energy for low temperature work, but for high temperature work it is advantageous to be able to get the material to a very high temperature when desired.

MR. EDGAR STANSFIELD:—I would like to ask Mr. Bennie why the use of calcium was abandoned?

MR. BENNIE:—If you introduce metallic calcium into a bath of steel containing more or less oxide, the result is likely to be violent, whereas by introducing a ferro alloy, such as ferro titanium, and having the alloy of approximately the same melting point as the bath into which it is to be placed, it is gradually melted, and the action is not so violent, although much gas is given off.

I do not think calcium would work as well as ferro-titanium.

MR. SCOTT:—Has any other lining been used besides magnesite, bauxite and dolomite?

MR. BENNIE:—No, those are practically the only linings used—occasionally chromite is utilized.

MR. DAVIES:—What is the horse power or voltage required to run this electric furnace?

MR. BENNIE:—Generally 45 to 50 volts for each arc; that is to say, in a furnace having two arcs in series 90 to 100 volts and in a

furnace with one arc, 45 to 50 volts, the amperes being naturally a function of the amount of energy you want to put in. It is a matter of choice as to how much energy you wish to put into the furnace, because an electrical furnace is not rated in capacity like other furnaces. It has two ratings—electrical capacity and metallurgical capacity. You can take a given electrical furnace and put in 100 or 400 horse power according to how much voltage you put on.

MR. MASON:—Is there any objection to using fine ores in the manufacture of pig iron in an electrical furnace.

MR. BENNIE:—No, there is no more objection to using fine ores in an electrical furnace than in an ordinary blast furnace. There is the objection that you are generating a great deal of gas, and in the electrical furnace you do not have quite the same conditions. You have all your gas generated down below and even if the thing is blocked ever so little, the gas will come out around the electrodes; that is a very bad condition of affairs, having gas coming out there, because you get air burning of the electrodes, but that is an objection that will hold generally. Anything that is objectionable on account of its physical condition in a blast furnace, would be equally objectionable in an electrical pig iron furnace.

MR. T. DENIS: Mr. Bennie has announced that zinc is now being successfully treated electrically in Germany. May I ask if spelter is produced by this process?

MR. BENNIE: Yes; the furnace to which I have referred produces spelter without blue powder.

TOOL STEEL DIRECT FROM THE ORE IN AN ELECTRIC FURNACE.*

BY ALFRED STANSFIELD, D.Sc., Montreal.

(Annual Meeting, Toronto, 1910).

At the Eighth Annual General Meeting of this Institute, which was held in Quebec in 1906, Mr. J. W. Evans, then of Deseronto, gave an interesting account of some laboratory experiments which he had carried out during the previous two years on the production of tool steel directly from the ore in the electric furnace.†

Mr. Evans had been obliged to construct with his own hands the 1½ k.w. electric generator he used for these experiments—thus proving his ability and determination—while he demonstrated his audacity by basing a large electric furnace industry, in the Provinces of Ontario and Quebec, upon the results of his laboratory tests in which one ounce of ore was smelted at a time to yield a button of steel.

The experiments made at that time showed (1) that from a sulphurous ore, containing 1% of sulphur, low carbon steels could

*DR. A. STANSFIELD, in introducing his subject, said: "It is with a certain amount of diffidence that I come upon this platform in succession to Mr. Bennie. I might perhaps begin, if Mr. Bennie will pardon me, by recalling a statement he made that there was no electric furnace making steel at the present time in Canada. I would like to correct that statement, because, while perhaps there is no furnace turning out steel in tons, I have a rather interesting exhibit here of steel tools which have actually been made in Canada in an electric furnace in the course of the last twelve months, with the modification of course that at present I am not talking in tons but only in pounds.

I may explain that Mr. Bennie has been speaking of the production of pig iron from ore in the electric furnace, and he has also spoken of the production of steel from a metallic charge in the electric furnace. The particular subject on which I shall speak this evening is the direct production of steel from the ore. Such work for instance as was accomplished by Captain Stassano some years ago. Capt. Stassano was producing structural steel but found that his process was not commercially successful. I shall speak this evening of the production, not of structural steel, but of tool steel directly from the ore.

† J. W. Evans, Jour. Can. Min. Inst., Vol. IX, 1906, p. 128.

be obtained having 0.05% to 0.07% of carbon and 0.08% to 0.17% of sulphur, and (2) that from a titaniferous ore containing 45% of iron and 7.6% of titanium a steel could be obtained with less than 1% of carbon and with the titanium varying from 0 to 1%. The whole of the titanium could readily be removed by using enough lime in the charge, but it was desired to retain some titanium in the steel, on account of its valuable properties, and this could be done by using less lime. Lowering the amount of lime in the charge had, however, the attendant result of causing more silicon to enter the metal; the silicon ranging from 0.05% to 2.31% in the steel obtained. Some samples of electric furnace tool steel were shown which had proved satisfactory in small machine tools; they contained ½% of titanium.

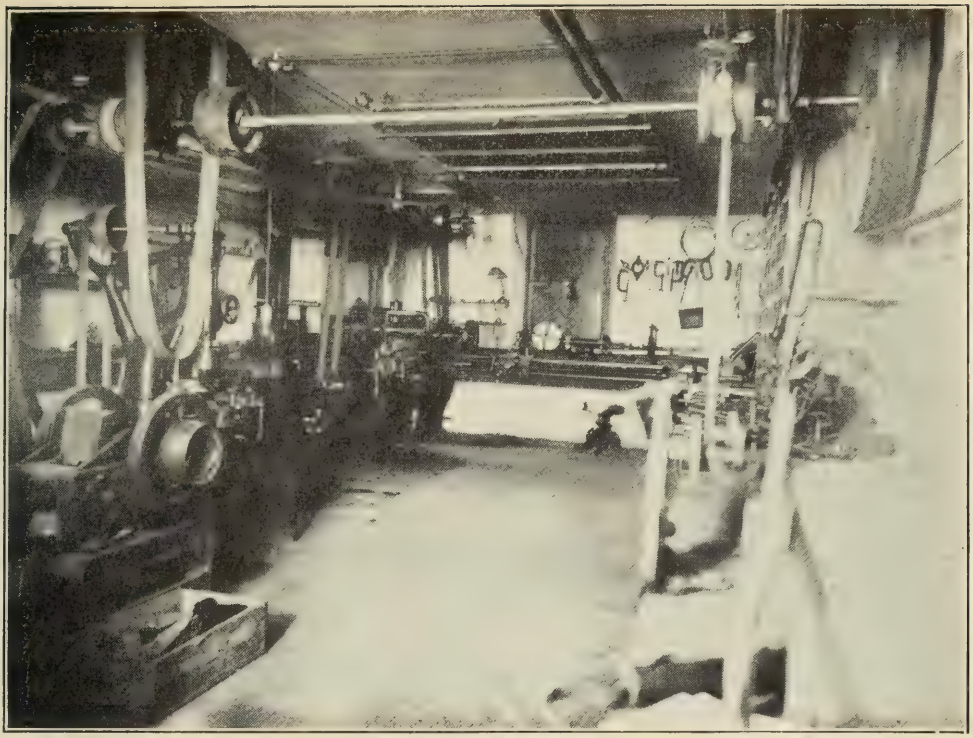
The writer, at the next meeting of the Institute, criticised these experiments on the ground that so small an amount of metal might be more perfectly refined than would be possible in a larger furnace working more or less continuously, and showed this to be the case, experimentally, in regard to the removal of sulphur from sulphurous ores.[1]

Since the date of his paper, Mr. Evans has been enlarging his electric furnace plant and has directed his experiments mainly to the production of tool steel from magnetite ores containing titanium and traces of vanadium. The writer had the opportunity last summer of inspecting Mr. Evans' plant and assisting in his smelting operations, and considered that an account of these might be of interest to the members of the Institute, although, owing chiefly to Mr. Evans' ill health, the data now available are by no means as full as could be desired and this communication can only be regarded as a preliminary note.

Mr. Evans' plant, last September, consisted of a small cylindrical furnace about 18 inches high and 14 inches in diameter, having a pair of lateral electrodes and supplied with electric current at 110 volts from a transformer of about 20 kilowatts capacity. A rheostat was used to regulate the current, and it was necessary to keep the latter below 200 amperes. In general, it was only possible to utilize some 6 or 8 kilowatts in the furnace.

Figure 1 is a section of the furnace and shows the original brick lining, B, eroded by the action of the slag in the furnace, and

[1] A. Stansfield, Jour. Can. Min. Inst., Vol. X, 1907, p. 129.



Mr. Evans' Workshop, West View.

Mr. Evans' Workshop, South View.

a lining, L, rammed into the cavity before each operation of the furnace. M is the melted steel in the furnace, S the slag and C the partly reduced but unmelted charge of ore, charcoal and limestone. The electrodes, E, are 1 inch square graphite rods provided with holders for supplying the current and capable of being inclined more or less during the operation of the furnace. The openings through which the electrodes entered were closed as far as possible with an asbestos mixture, and a couple of bricks served as a cover for the furnace.

The peculiar feature of the smelting practice in this furnace consists in the way in which the electrodes are manipulated. In the early part of each smelting run an arc is established between them, as in the Stassano furnace, and the heat of the arc is utilized for reducing the iron ore to metal and melting the metal and slag. The electrodes are shown in this position at EE. When the slag has filled up the furnace so as to immerse the ends of the electrodes, or by purposely depressing the electrodes into the slag, as shown at

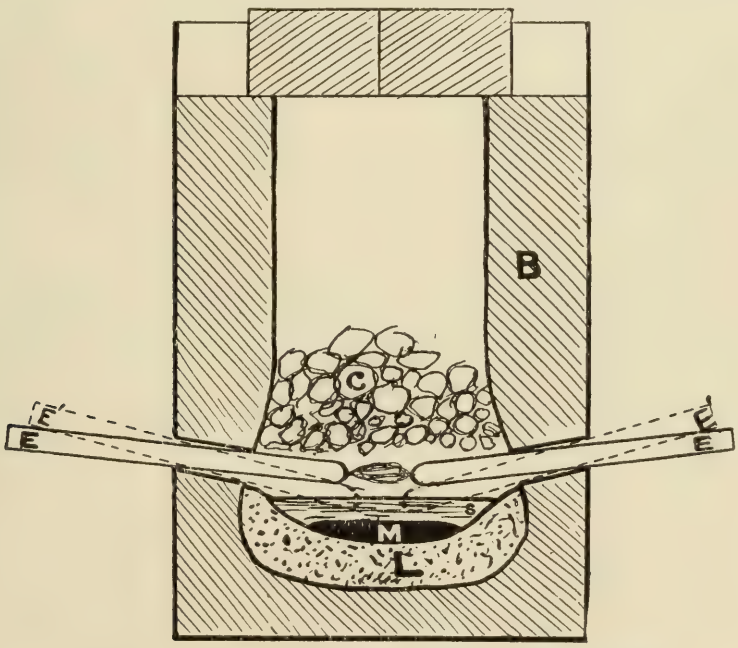


FIG. I. Small Furnace with two Electrodes.

E, E, the arc is stopped and the current flows from one electrode to the other through the molten slag and metal. Mr. Evans found the latter method of heating to be more satisfactory and considered it essential for the refining of the steel.

The behaviour of the furnace was somewhat peculiar in this particular:—When running with the arc between the electrodes EE, the resistance was very low, so that the electrodes had to be drawn widely apart and even then a current of 200 amperes was produced with a voltage of only 30 or 40. Immediately the electrodes were dipped into the slag at E, E, and the arc broken,the resistance was increased so that 60 volts only produced a current of 100 amperes or less. This condition was unstable, as there was always the possibility of an arc forming between the electrodes, above the slag, and this would immediately cause a great increase in the current. As the immersion of the electrodes in the slag led to a heavy loss of the electrodes, the attempt was made to keep them just above the slag and to maintain a short arc between each electrode and the molten slag. Owing to the high resistance of the slag, this was found to be impossible, but a later type of furnace has been found to work very satisfactorily in this way.

The ore treated was a magnetite from the Orton mine in Hastings County, Ontario, and contained:—

Iron	51·45%
Sulphur	trace
Titanium	7·50%
Nickel	0·12%
Vanadium	trace

For smelting on a small scale it was found desirable to crush the ore, the charcoal used to reduce it and the limestone used as flux. These powders were mixed together, briquetted with the aid of molasses and water and baked before smelting, a typical charge being:—

Ore	100 oz.
Limestone	20 "
Charcoal	18 "
Molasses	10 "
Water	16 "

Starting with a hot furnace and using between 5 and 6 kilowatts, the operation would be completed within the hour and would produce about 3 lbs. of steel.

The steel was tapped from the furnace without any addition of ferro manganese or other deoxidiser and always gave a perfectly sound and tough ingot. Mr. Evans has obtained in this way many ingots of steel, which have proved to be a very good quality of tool steel. Unfortunately at the time of the writer's visit the lining material had become contaminated with a little plaster of Paris and, in consequence, the steel was found to contain over 0·10% of sulphur, which impaired its forging quality, though it made good tools. The presence of sulphur in the furnace lining was not discovered until it was too late to obtain a fresh supply. One sample of steel, from which good lathe tools were made, contained:—

Carbon.	1·25%	Phosphorus.	0·051%
Silicon.	1·06%	Titanium.	Nil
Sulphur.	0·124%	Vanadium.	Nil

Mr. Evans has found that the steel produced by the direct reduction of this titaniferous magnetite in the electric furnace has peculiarly valuable qualities as a tool steel. He attributes these to the titanium and perhaps also to the nickel and vanadium in the ore. Non-titaniferous magnetites, from the Rankin mine did not yield sound steel when smelted in Mr. Evans' electric furnace.

He has submitted samples of his steel to various steel experts, obtaining very satisfactory reports, and a piece of his steel made into a lathe tool and tested at McGill was found to compare favourably with a standard tool steel. The tool was tested just as received from Mr. Evans. It was ground when necessary but not retempered. The tools were usually cut from the ingots —not forged—but a knife has been forged from some of this steel.

In connection with these tests it should be noted that in operating a small furnace it is not practicable to take a sample of the steel from the furnace and make a quick chemical test of it, as would be done with a larger furnace, and that, in consequence, the composition of the steel could not be adjusted in the furnace and the analysis of the resulting steel will not in general be as good as it could easily be made when working on a larger scale. It should also be noted that no ferromanganese or other additions have been made to any of the steel obtained up to the present.

It is, therefore, quite likely that when working on a larger scale, steel can be produced of even better quality than has so far been obtained, and it is certain that the steel can be obtained of practically constant composition.

At the meeting, a number of tools were shown which had been made from steel produced in the Evans furnace. A photograph of the set of tools is reproduced in the plate. Several of these tools were made from a bar of steel which analyzed:—

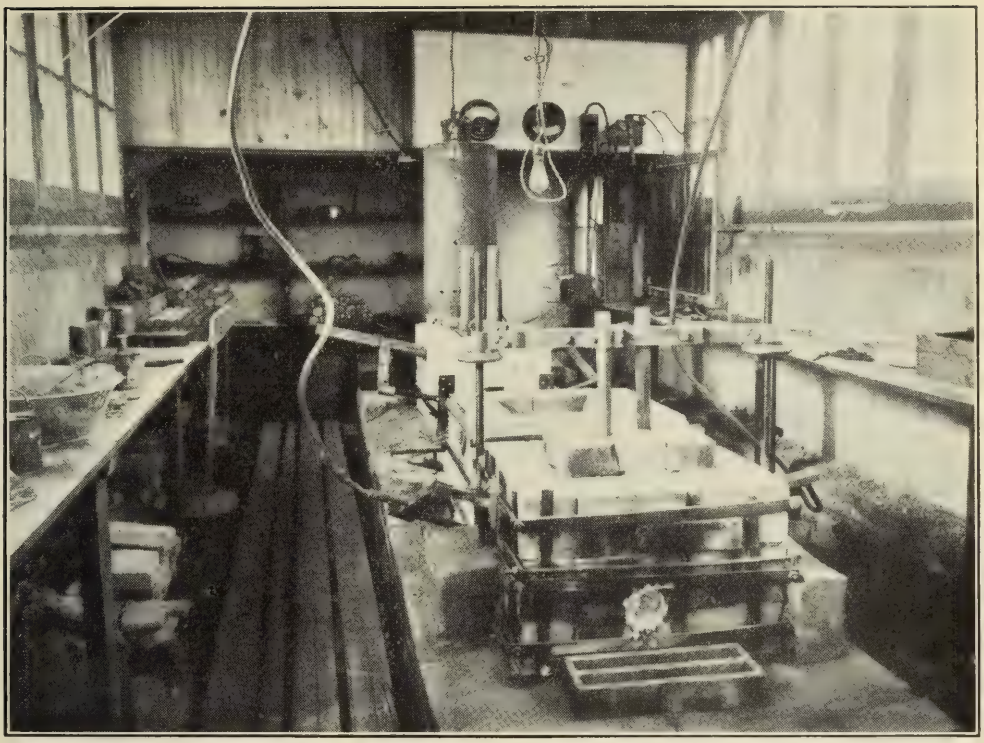
Carbon.	0·91%	Titanium.	trace
Sulphur.	Nil	Vanadium.	Nil

Mr. Evans has quite an extensive workshop in which he constructs his furnaces, crushes the ore and fluxes, and tests the steel he obtains. Views of this are given in the accompanying photographs.

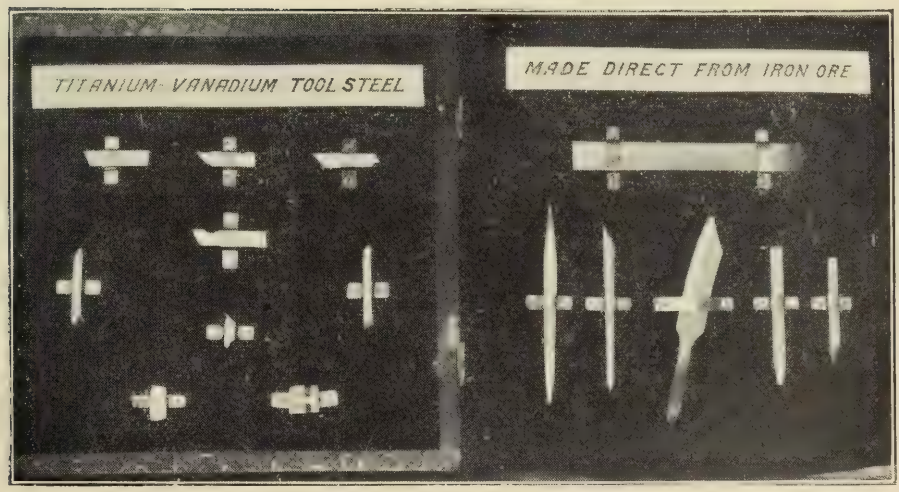
If it is admitted that a good tool steel can be made directly from the ore in the electric furnace, the most important remaining question is whether the cost of the process will be low enough to render it commercially practicable. With this object in view the writer made careful observations of the consumption of charcoal, limestone, electrical energy and electrodes in Mr. Evans' experiments, and the results of these observations may be stated as follows:—

1 lb. of tool steel reduced in the small electric furnace required
2·1 lbs. of magnetite ore from the Orton Mine.
0·4 lbs. of limestone.
0·4 lbs. of charcoal (including carbon in binding material).
0·08 lbs. of electrodes (Acheson graphite electrodes at 12c. a lb.).
3·0 kilowatt hours.

Most of these figures could undoubtedly be reduced in the case of a larger furnace, and it will be safe to state that a furnace making one ton or upwards of steel in 24 hours would not require more than 0·35 lbs. of charcoal and 2 kilowatt hours per lb. of steel, while the electrode losses could certainly be reduced to not more than half the above figure, or say 0·03 lbs. per lb. of steel. Taking the electrical horse power year at $20, the cost of 2 kilowatt hours would be 0·62c., and the electrodes would cost 0·36c., or a total cost for ore, charcoal, limestone, electric power and electrodes of about 2 cents per lb. of steel. The electrode losses in the



Furnace Room, with small Furnaces.



Tools made from Electric Furnace Steel.

test runs were greatly increased by the practice of allowing the ends of the electrodes to dip into the slag in the furnace. If, as is the case in the larger furnaces, the electrodes do not enter the slag, but are merely employed for producing an arc, the losses should be very much less. The rate of loss must also be proportional, more or less, to the surface of the electrode, and as the surface of the electrode, or at least of the hottest part of the electrode, becomes proportionately less in larger furnaces, there is no doubt that a decided improvement will be shown in this particular.

Independent information with regard to the cost of running such a furnace on a somewhat larger scale can be obtained from the published test of the Stassano furnace in Italy made by Dr. Goldschmidt, in 1903[1]. The test was made on quite a small furnace of about 80 kilowatts, turning out 70 lbs. of mild steel in two hours, smelted directly from pure hematite ores. One pound of steel required:—

1·63 lb. hematite ore.
0·20 lb. limestone.
0·26 lb. charcoal.
0·20 lb. carbonaceous additions.
0·012 lb. electrodes.
1·44 kilowatt hours.

These figures confirm what has been stated above with regard to the probable cost of the Evans process on a working scale and show that even better results may be expected.

The cost of labour, management, etc., will vary so much with the locality and particularly with the scale on which the plant is constructed that it does not seem worth while to attempt to estimate them. It may be mentioned, however, that Dr. Goldschmidt, in the report already referred to, states that in a plant of 5,000 h.p., located in Italy, producing 30 tons of steel in 24 hours, from rich hematite ores, the total cost of the steel, including ore, power, electrodes, labour, maintenance, etc., but not apparently interest or depreciation, would be very close to 1 cent per lb.

In connection with the above figures it should not be forgotten that the best tool steel is not rolled from the ingot but is

[1] Electro-chemical Industry, 1903, Vol. I, p. 247.

drawn down under the hammer to obtain the finished bar. The cost of this process would have to be considered in determining the cost of production of the steel bars.

In Mr. Evans' experimental furnace only two electrodes were employed, and these could be placed nearly horizontal, or could be inclined at an angle in order to enter the slag. On the large scale it is intended to attain the same results by having two pairs of electrodes; one pair being vertical and the other nearly horizontal. This arrangement, which is shown in figures 2, 3 and 4, enables the horizontal electrodes to be used, as in the Stassano furnace, for the purpose of melting the charge, while the vertical electrodes can then be substituted and used as in the Heroult furnace for heating the molten charge during the finishing stages of the process.

Figure 2 and the plate show furnaces of this kind which Mr. Evans has constructed. The lateral electrodes are slightly inclined so that the arc may be near the charge while the openings through which the electrodes enter may be well above the slag level. The vertical electrodes pass through the roof of the furnace, and their holders are insulated from each other but are bolted together for greater strength. In this way the two electrodes are regulated together. In these furnaces it is necessary to withdraw the lateral electrodes before the vertical pair can be lowered into position, but in a larger furnace the electrodes could be placed so as not to interfere with each other, as in the right hand drawing in Figure 3.

With the furnaces shown in Figures 1 and 2, the ore is introduced directly into the body of the furnace, as is also the case with the Stassano furnace. In the latest designs, see Figure 3, Mr. Evans is adopting a suggestion of the writer and adding a tower, in which the ore is heated and partly reduced before it enters the electric furnace itself, and this modification should effect a considerable saving of electrical energy and even of charcoal and electrodes.

When promising this paper for the Toronto meeting, the writer expected to be able to make further tests with Mr. Evans' furnace in order to obtain more exact data for the cost of operation, and to have a supply of steel for a full set of chemical and mechanical tests. Mr. Evans' unfortunate illness prevented these tests and the writer was therefore unable to present as complete an account as he would have liked of this interesting process.

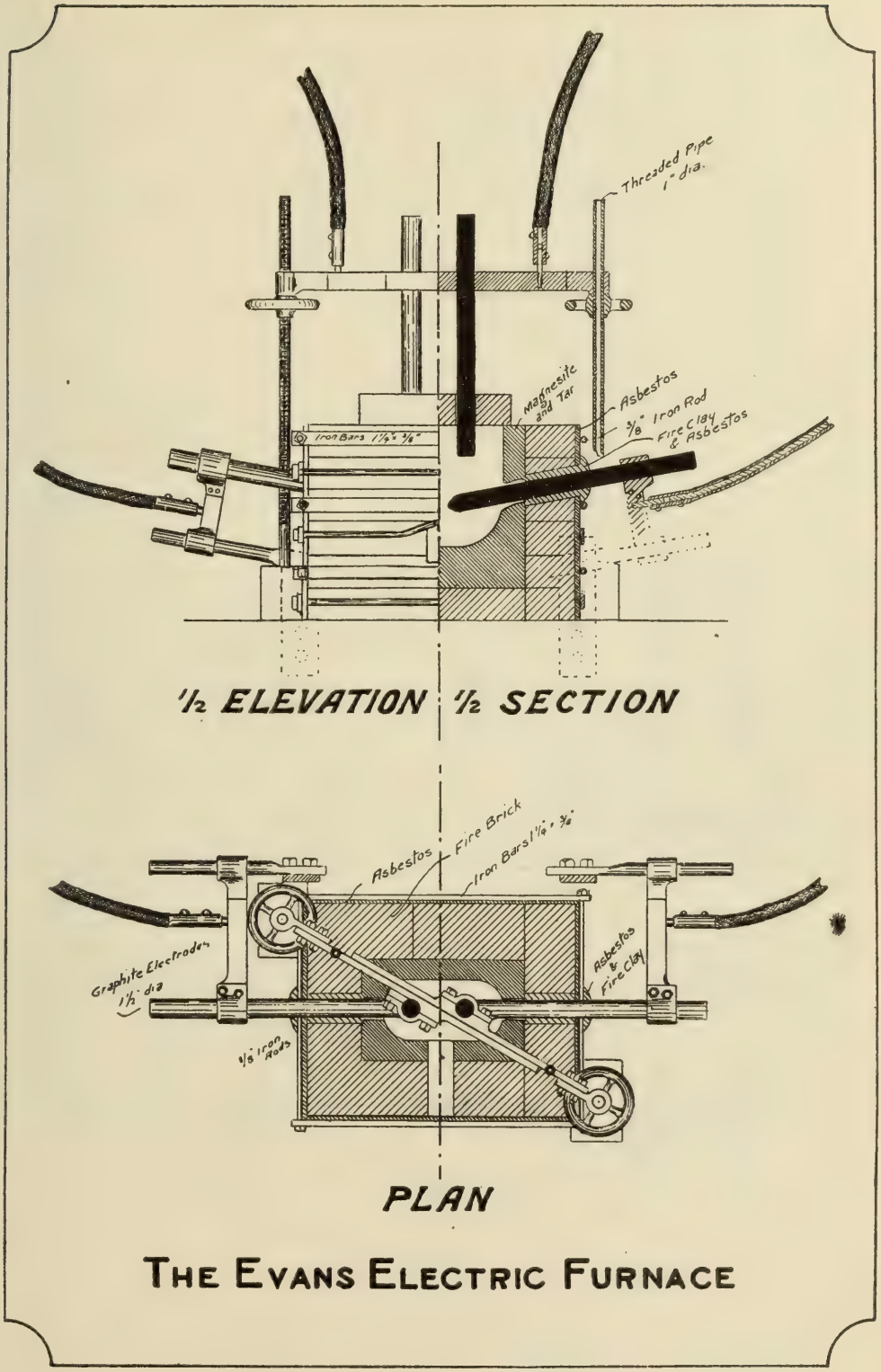

Threaded Pipe 1" dia.
Magnesite and Tar
Asbestos
⅜" Iron Rod
Fire Clay & Asbestos
Iron Bars 1½" × ⅜"
½ ELEVATION ½ SECTION
Asbestos
Fire Brick
Iron Bars 1½" × ⅜"
Graphite Electrodes 1½" dia
Asbestos & Fire Clay
½" Iron Rods
PLAN
THE EVANS ELECTRIC FURNACE

FIG. II.

Mr. Evans has acquired the Orton Iron Mine, in Hastings County, and informs the writer that more than 2,000,000 tons of titaniferous iron ore has been proved there by the diamond drill. The core shows the ore body to be 60 feet wide at 280 feet below the surface. The last analysis of the ore gave:—

60·84% iron, 7·5% titanium, 0·11% vanadium.

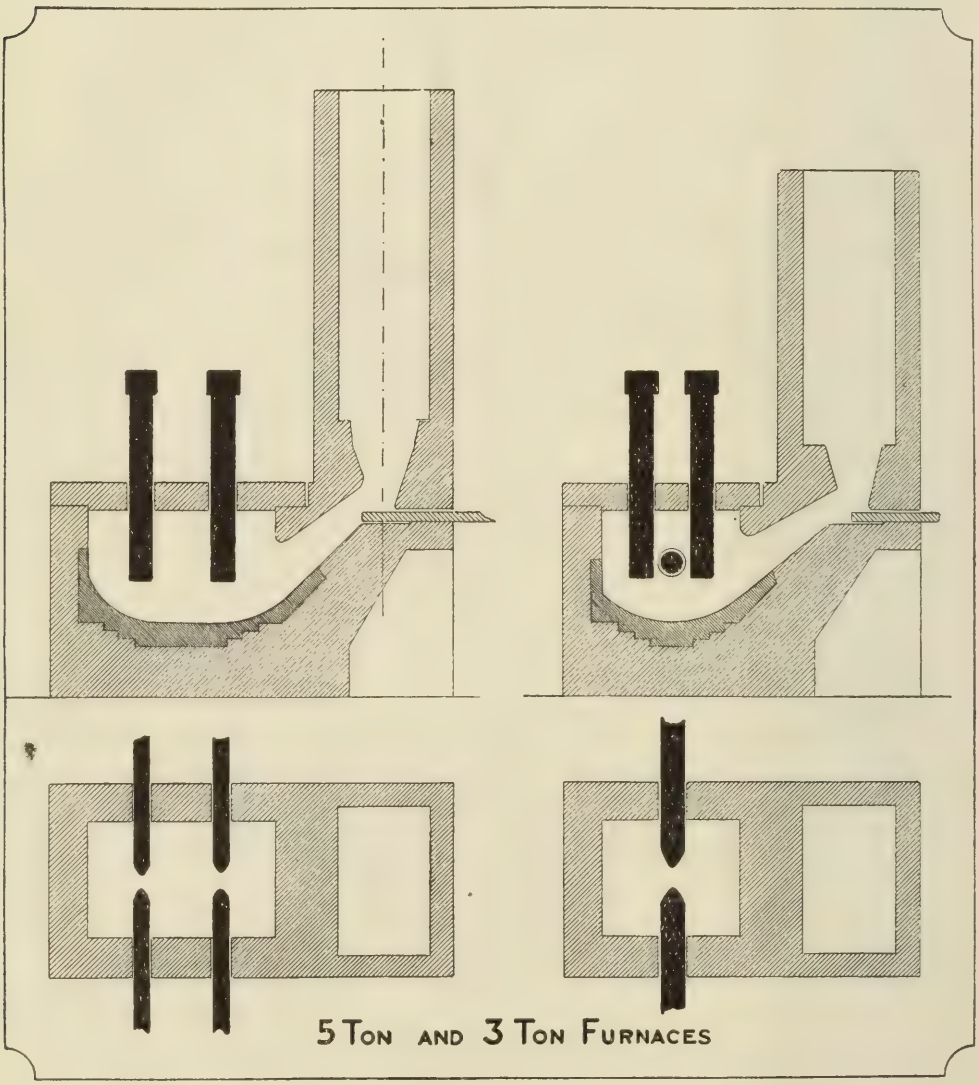


FIG. III.

There is a quantity of limestone on the property, an abundance of wood for charcoal, and power can be brought from Campbellford at a reasonable figure.

The process of making steel in the electric furnace from titaniferous magnetites, which was inaugurated on such a small scale four years ago, should prove of great value in Canada, where these ores, charcoal and water power are all available, and where tool steel is at present imported.

DISCUSSION.

MR. BENNIE:—May I enquire, if it is not inconsistent with Mr. Stansfield's connection with these experiments, whether there was any metallic titanium in the steel.

PROF. STANSFIELD:—Titanium is sometimes obtained in the steel, as is mentioned in the paper, but it was not present in the analysed products of any of the tests with which I was connected.

MR. BENNIE:—Was there any nickel?

PROF. STANSFIELD:—Nickel is found in some samples of the ore, but I have no analyses showing its presence in the steel?

MR. BENNIE:—What is the nature of the slag used to combine with the titanium?

PROF. STANSFIELD:—In Mr. Evans' work he finds that the addition of lime in the furnace lowers the titanium in the steel.

MR. DAVIES:—I would like to ask Prof. Stansfield this question: At 110 volts, or as he stated, at 80 to 90 volts, how far apart are the points of the electrodes?

PROF. STANSFIELD:—I do not know that I can give a very satisfactory answer to that question. With that voltage we were using electrodes very close together, only a few inches apart. In Stassano's experiments his furnaces were about one meter across, and under those conditions it is stated that the electrodes were in some cases nearly one meter apart, with a voltage of about 150 volts.

MR. OBALSKI:—What is the action of the titanium chemically?

PROF. STANSFIELD:—The titanium has apparently two actions. Starting with titaniferous ore, you may have steel which contains a trace of titanium or steel without any trace at all. If you have

titanium in the steel it has a direct effect on the nature of the steel, a beneficial effect in small quantities, but apart from that the titanium has an effect even if it does not enter the steel, apparently a washing effect in removing possibly the oxygen and nitrogen from the steel itself. It is conjectured at any rate that one use of titanium when it does not enter the steel or when it does enter the steel, is in the removal of these two gases. All I can say is that the steel that has been obtained appears to be of very good quality. I have not been able to make a very complete test, but Mr. Evans sent me a small piece of tool steel which was tested at McGill University and it was found to be decidedly better than ordinary tool steel.

THE RECORDING AND USE OF COLLIERY COST DATA.

By F. W. Gray, Glace Bay, C.B.

(Annual Meeting, Toronto, 1910.)

The cost-sheets of a colliery company, and the general cost data may be divided into three main branches, namely:—

a. The cost of mining coal, and delivering it into cars at the pit mouth.

b. Data connected with costs, but of a technical nature intended for the guidance of the mine superintendent.

c. Complete cost calculations, for the guidance of the directorate, which include fixed charges such as royalty, bond interest, taxes, etc., of a private nature.

With this last-named division this paper will not deal, as it comes under the head of book-keeping rather than under that of cost-keeping, and these two operations should not be confounded. The innate differences between cost-keeping and book-keeping are well dissected in a recent work by Gillette & Dana,* but they can be largely summed up in one sentence, quoted from their work, namely: "Book-keeping is a clerical function; cost-keeping is an engineering function." The authors of this book remark that many persons confound cost-keeping with book-keeping and attempts are often made to make a cost-keeping system "so elaborate as to be a book-keeping system, thus burdening the book-keeping with a great deal of material that is not germane to it and piling the cost system under an avalanche of details and figures that are destructive to its economic value." While these words were intended to refer more particularly to general construction work and for the guidance of contracting engineers they are none the less true of colliery cost-keeping. Colliery costs do not admit of too much elaboration, and it is a mistake to attempt

* Cost-keeping and Management Engineering, Gillette & Dana.

a great refinement of detail in designing the cost system of a coal mine. This is particularly true of the underground part of colliery expenditure, where the surroundings do not favor the niceties of book-keeping, and where the officials are often much more concerned with the immediate actualities of a "smash on the deep" than with what they are disposed to consider as the "frills" of the cost-keeping system. In this respect a colliery cost system is not comparable with the very elaborate systems that are used in large manufacturing establishments and factories. The greater the simplicity of a colliery cost system and the more easily it may be grasped by the average pit official, the more likely it is to succeed in detecting the weaknesses and lack of efficiency in the organization. It is of the nature of things, and well known to every person who has had experience in the watching of colliery costs, that the most excellent and capable pit-man may not necessarily be a good bookkeeper, yet this same man will in every probability prove a valuable assistant in keeping down costs if the system is designed from the pit-man's point of view, rather than from the standpoint of the accountant. For this reason it is necessary that the design of a cost-keeping system for a colliery should be made by persons acquainted with the actual conditions that are connected with the mining of coal and its delivery at the pit bank.

The process of comparison is, of course, the chief guide to the effecting of economies and the elimination of unnecessary expenditure, and in so far as a cost system permits of easy and pertinent comparison it will be found effective. The "unit cost" of coal mining is the ton-weight, and with the possible exception of a few tables which come under division "*b*" previously referred to, it will be found that most of the calculations connected with the extraction of coal are made on the unit cost of a ton of coal. Everything should be designed with a view to enabling the easy compilation of comparative tables, and in this regard nothing will be found more useful than a series of permanent tabulated records so arranged that they can be augmented from month to month.

The principle of progression is an important one in a colliery cost-keeping system. In most cases it will be found that the longest way round is the nearest way home. The original records from which a cost sheet is assembled are the time books and the

warehouse delivery sheets. The picking out of the details from these two main sources should not be done on loose scraps of paper which are thrown away as soon as the preliminary work is done. For all the work in a colliery office which is a matter of daily routine there should be provided standard printed forms, and with the exception of the mere arithmetical calculations, there should be a record of every step in the compiling of the cost-sheet from the time book and the material sheets to the completed figures of the yearly summary. The daily entries should be so arranged that they can with ease be added up and averaged for the monthly entries, and the monthly entries in their turn should be transcribed in such a way that they form the permanent record arranged in years. In actual practice it will be found that such a method will facilitate the work of those who are responsible for the records. Where costs and wages are calculated on a monthly basis it is often the case that the work of the clerks is unequal. The fortnights and the month-ends bring with them a rush of work, while the intervening periods are often slack. This state of affairs is good neither for the clerical staff nor for the accuracy of the records, and it causes considerable delay in bringing before the attention of the heads of departments matters of which they should be informed at the earliest possible opportunity. It will be found good practice that every day should see the conclusion of the work belonging to it, and each detail should be so entered up that at the month end nothing more is necessary than to add up and summarize the various columns. Under such an arrangement the work of the office will proceed with easy regularity, and will not be marked by alternate periods of rush and laxity.

The actual working of any particular system of cost-keeping will have to be decided, to a large extent, by the system of paying wages, whether this is weekly, fortnightly or monthly, but it will generally be found convenient to keep all permanent records on a monthly and yearly basis, corresponding to the calendar. Opinions differ as to the value or necessity of *daily* cost returns, but here again there is often confusion between costs and book-keeping. Daily cost returns can only be approximations, particularly as regards contract work, but this is quite sufficient for the end in view. If the figures of the mine cost are made up only at fortnightly or monthly intervals several days will elapse between the end of the period and the date on which the completed cost returns will be available

for the use of the management. There is then a tendency to look rather for explanations of increases or decreases, and to spend time in hunting these up which would be more profitably occupied in preventing the irregular variations from having occurred. Apart from the considerations previously urged as to the principle of progression, a daily record of costs affords the management an opportunity to remedy wrong conditions immediately, and as they come about. It enables the manager to keep a close watch on his expenditure for material supplies, and upon his subordinate officials and his organization in general, and leaves no room for excuses on the ground of ignorance of conditions. If the daily returns are properly designed any abnormal condition is at once apparent, and the manager can prosecute his enquiries in time to prevent any unnecessary prolongation, if the condition is such as permits of remedy.

The work of a colliery is performed by two classes of workmen, namely the "producers" or those who actually dig the coal at the face, and secondly, by the "non-producers" or the auxiliary class of workmen, whose business it is to take the coal away from the face, deliver it at the pit-mouth and prepare it for market. The latter class includes all the surface workmen. The cost of production depends very largely on the proper balancing of the mine organization between the producers and the auxiliary workmen. For the reason that the first-named class are generally paid on contract rates, it is not necessary to devote much attention to the supervision of their earnings, but the auxiliary class is chiefly composed of day-wage workmen, and it is necessary to devote a good deal of attention to the number and wages of these men. It is most important to a colliery manager that he shall be informed daily of the exact number and distribution of the men who are under his charge, arranged in such a way that he can compare it easily with previous figures of the same nature. By arranging the force return in three main groups, namely, surfacemen, underground labour and contract mining coal he can see by a glance at the totals whether his force is economically disposed or not. If for example he observes that the number of men mining coal is lessening, while at the same time the number of auxiliary workmen remains constant or possibly increases, the manager may confidently anticipate a reduced tonnage and an increased cost. The remedy may be in putting on more miners, or it may

be in reducing the force of labourers, and the manager will find it necessary to investigate. Such investigation to prove of any benefit should be undertaken immediately.

A useful method for checking up irregularities in force and cost is to have prepared about the first of the month a forecast estimate of the cost of producing coal for the month. This estimate would be based on previous good performances of the same mine. Given a certain output required the manager will detail on the standard forms what he considers the proper number of workmen and their best distribution. Day by day as the month goes along he will compare the actual figures with the estimate, and will require explanations of marked variations therefrom.

There are two generally accepted methods of recording and comparing the costs connected with the mining of coal. In one method the cost is dissected into the various operations of a colliery, such as "coal cutting," "mechanical haulage," etc., as under:

Tons for Month.....

CLASSIFICATION	LABOUR		MATERIAL	
	Amount	Per Ton	Amount	Per Ton
Administration				
Coal Cutting				
Mechanical Haulage				
Horse Haulage				
Roads				
Timbering				
Ventilation				
Repairs to Pit-tubs				
Hoisting				
Screening and Loading				
Pumping				
Miscellaneous				
Total				

All expenditure is dissected into two main items of "labour" and "material," and is split up and apportioned among the several items of operation by means of a daily dissection sheet. The completed cost-sheet is a very compact and workmanlike appearing sheet, and affords an admirable summary of the components of the mine cost. It does not however meet the necessities of the colliery manager, and this system was probably not devised by a person practically acquainted with the actual operations of mining coal underground. Even to the man on the spot, it is a difficult matter to say where for example "horse haulage" ends and where "mechanical haulage" begins, or when the exact division occurs between the last named operation and that of "hoisting." In the same way, it seems quite difficult to correctly divide the item of "timbering," or to say what the difference is between "roads" and "timbering." By the time the labour cost has been sub-divided among the various headings of mine operation such important details as the wage rates and the number and balancing of the mine force are lost in the mazes of the dissection. If the cost per ton of any particular operation shows an increase, it will be found necessary to wade back through the sub-divisions of the dissection and reconstruct the original record from which the analysis was arrived at, namely, the time book and the warehouse sheet. In this method also no separation is attempted of the surface from the underground force, and for example the item of "pumping" would include the pumpmen underground, the time of machinists repairing pump-parts on the surface, and a proportion of the labor cost connected with the air-compressors or other power generating plant. At all collieries, of course, the power plant, *i.e.*, the boilers, and the air-compressors, or the electric generators, as the case may be, are common to all the operations, and in the working of a cost-sheet such as that now under consideration it is necessary to keep an account known as "motive power" which does not appear on the cost-sheet as such, but is distributed among the various operations that require motive power, as for example, "coal-cutting," "mechanical haulage," etc. In the same way "material" is dissected, and, to take a concrete example, the money expended for a barrel of oil might be represented by the "material column" of half-a-dozen varying operations. In the case where several seams are worked from one shaft with a common power-plant, it is necessary, if the cost

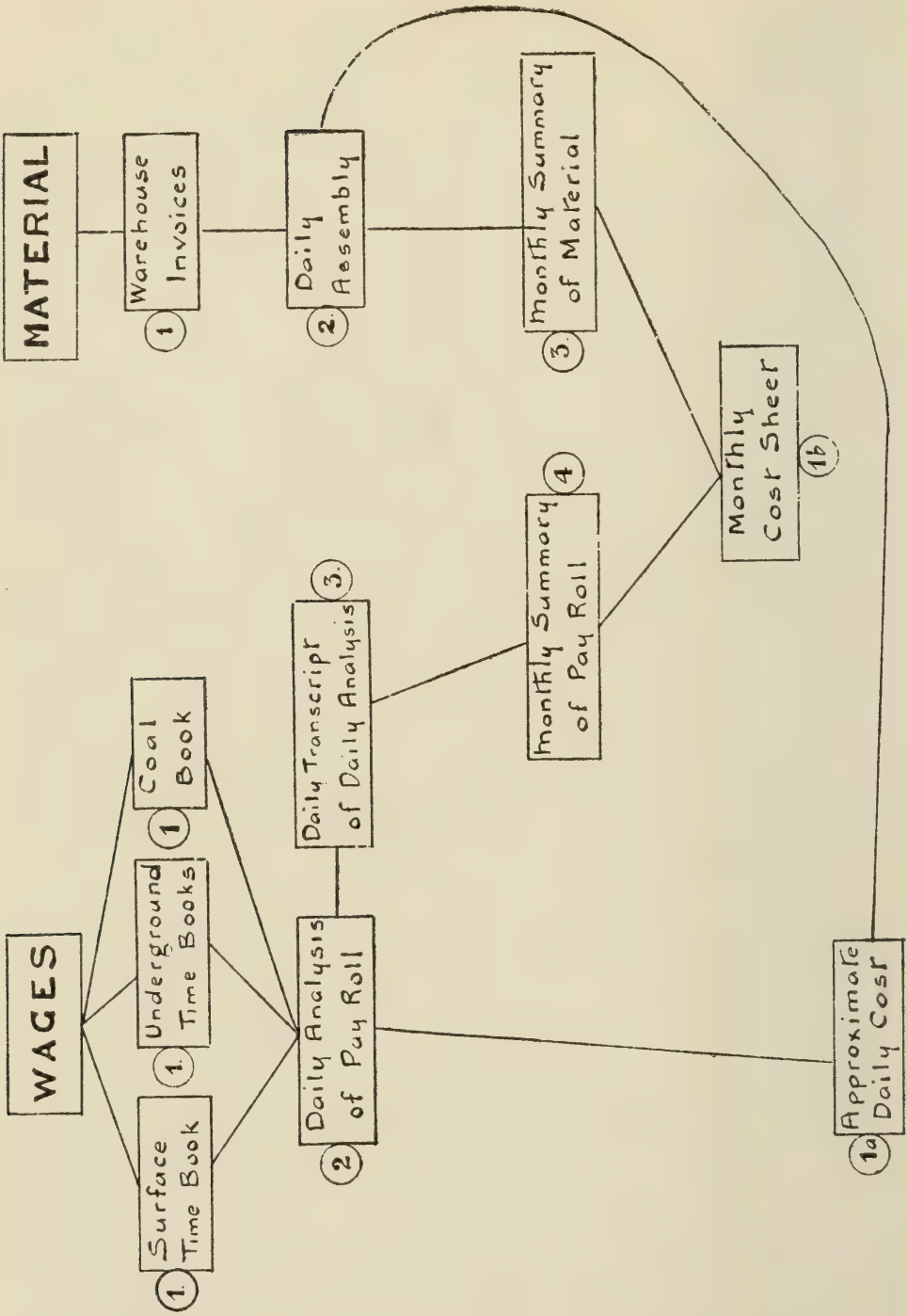
of each seam is to be kept, to again sub-divide such an arbitrary account as "motive power" into a *pro rata* proportion of the cost based on the output of each seam. If on about the fifteenth of the month following a manager is asked why certain items of his cost-sheet show an increased cost per ton, it is not a matter for wonder if he is unable to explain. For while he would in all probability remember the purchase of several new horses, or a new haulage rope, a fall of stone on the haulage road, or some of the hundred and one things which may raise the cost of coal per ton, the form in which these expenditures appear on the cost-sheet is from the manager's point of view meaningless and unintelligible. The reason is not far to seek. This particular cost-sheet is a concrete example of what Messrs. Dana & Gillette designate as "the innumerable blunders which have been made in the attempt to graft a cost-keeping system upon a book-keeping system."

The second method consists in making the cost-sheet nothing more nor less than an orderly summary of the pay-rolls and the warehouse supplies, in which it is possible to see, for example, that in "horse haulage" there were employed a certain number of drivers making a certain daily wage, and aggregating a certain sum, bearing a certain relation to the output. In the "material" division the items of expenditure are shown like the listing of an ordinary invoice as to quantity, kind and cost.

To take a concrete example,—the fact that in the month of July a colliery consumed an appreciable number of gallons of cylinder oil more than it did in the month of June, or in the month of July in a previous year, is much more likely to appeal to and impress the men in charge than to say that the item of "motive power" was a fraction of a cent higher than usual. It is also much more likely that the remedy will be applied, because it is possible to see just where the fault lies and in what it consists.

Dealing with the second method in detail, the steps and standard forms necessary for the carrying out of the ideas outlined previously are roughly indicated by the following diagram.

Taking the order of the diagram, the time books call for first consideration. These, and the weighman's record of coal passing over the pithead scales, form the basis of the labour cost. The time books are arranged to conform, as far as is possible, to the arrangement of the "Daily Analysis of Pay Roll" (form 2). If the



check time-office system is used it will give sufficient safeguard against errors or manipulation of the time books, but where no system of this kind is in use, the management will find it necessary to exercise constant vigilance over the foreman or timekeepers

who mark the time, and to institute occasional checks, or lax methods may creep in.

Daily Analysis of Pay Roll (*Form* 2).—The form which follows is not complete, being only partially sketched, but sufficient has been shown to give a general idea, which is applicable to most cases, although the exact arrangement of this form will of course vary with individual requirements:—

DAILY ANALYSIS OF PAY ROLL

COLLIERY No.....

.....19.....

Class.	Assembly Column	Surface.					Underground L.	Mining Coal.
		Number of men employed.		Rate per Day	Total Wages.	Extension Total		
		Day	Night		Day / Night			
1. Screening.....	.....	.....	.....	.....	.....	.....	.....	.....
2. Foremen and Clerks...	.....	.....	.....	.....	.....	.....	.....	.....
3. Enginemen.....	.....	.....	.....	.....	.....	.....	.....	.....
4. Firemen.....	.....	.....	.....	.....	.....	.....	.....	.....
5. Mechanics.....	.....	.....	.....	.....	.....	.....	.....	.....
a. Machinists.....	1111	4		225	900		.....	.....
"	11	...	2	175	... 350	1250	.....	.....
"	.....	.....	.....	.....	.....	.....	.....	.....
b. Electricians.....	.....	1	.....	200	200	200	.....	.....
c. Smiths.....	.....	1	.....	225	225	.....	.....	.....
"	1111	4	.....	180	720	.....	.....	.....
"	11111	5	.....	160	800	1745	.....	.....
d. Carpenters.....	.....	1	.....	225	225	.....	.....	.....
"	1111	4	.....	190	760	985	.....	.....
"	.....	.....	.....	.....	.....	.....	.....	.....
Etc., etc.....	.....	.....	.....	.....	.....	4180	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	RECAPITULATION.	
	.....	.....	.....	.....	.....	.....	Total Surface.	
	.....	.....	.....	.....	.....	.....	" Underground.	
	.....	.....	.....	.....	.....	.....	" Mining Coal.	
	.....	.....	.....	.....	.....	.....	.....	.....

As will be seen from the sketch above the sheet contains three sets of columns, for the main divisions of labour, namely "surface," "underground labour," and "mining coal," each of which is arranged similarly to the one shown. Each class of workmen has a distinguishing numeral, and is divided into sub-classes, under alphabetical notation, which gives a time-keeping symbol for each sub-class. For example, on the sheet shown, a machinist would be indicated by the symbol "5*a*." The method of using the assembly column to facilitate picking off time and rates from the time books is illustrated by the examples given on the sheet above. The sheet is designed to enable the clerk to assemble the daily analysis easily and without confusion or use of scrap paper. At first sight the method may seem elaborate, but actually it involves just the same amount of calculation that a less orderly procedure would entail, with the added advantage of a permanent record. It may be remarked that nothing is so cheap as paper. When completely entered up the sheet affords for the inspection of the manager a complete and intelligible summary of the working force, the rate of wages, and the balancing of the organization.

Daily Transcript of Form No. 2.—This form is nothing more than Form 2 with the headings arranged for horizontal transcription, with lines sufficient for one month, or whatever period it is decided to cover. A glance up the columns of the transcript will show the daily variations in force and cost for every sub-class of labour employed, and at the end of the month the addition and averaging of each column will give the particulars necessary to fill in the "Monthly Summary of Pay Roll" Form 4.

Monthly Summary of Pay Roll Form 4.—This form is exactly similar to Form 2, with the modifications necessary to change a daily sheet into a monthly one, with additional columns for information which the completed figures for the month make it possible to calculate—see under:—

Month of.....19.....

MONTHLY SUMMARY OF PAY ROLL

Colliery No.....

		Surface				Under-ground	Mining Coal
Class	Daily Average Force	Total No. of Shifts work'd	Average Daily Rate	Amt.	Amt.		

The "Average Rate" column is filled in from the result of dividing the total wages by the total number of shifts worked. The "Average Daily Force" is the result of dividing the total number of shifts worked by the number of days the mine worked. Sundays and holidays are taken out when calculating this average. By a horizontal transcript of this form month by month is obtained a tabulation of great value, the inspection of which will give quickly, the average number of men employed in any one capacity, their average daily remuneration, and the distribution of the organization in any month so far back as the record may happen to extend. The clerical labour involved in making this transcription monthly is but trifling when compared with the ease with which data can be extracted when it is required, and the facility with which comparisons may be made.

The "Material" Cost.—The basis of the arrangement of the "material" cost is a standard classification, or index, which is designed to eliminate all duplication and vagueness. This standard index is printed on stout cardboard sheets, and placed in the warehouses and offices for permanent reference. Each main heading is indicated by a letter, and each sub-division by a numeral. For example on the index the main division of "Horses and Horsekeep" is detailed as follows:—

A. *Horses and Horsekeep—*
   1. Horses.
   2. Oats.

3. Hay.
4. Other feed outside hay and oats.
5. Medicine.
6. Stable fittings and supplies, brushes, curry-combs, forks, etc.
7. Harness—all harness material, as shafts, bows, hames, rein-rope, trace-chains, rugs, etc.
8. Horse shoes, nails and farriers' tools.
9. Vehicles and repairs, wagons, carts and all parts.

On the "Monthly Summary of Material" (Form 3) this division would appear in condensed form as follows:—

Month of.....19.....

MONTHLY SUMMARY OF MATERIAL

Colliery No.....

Class	Quantities	Unit of Measurement	Amount		Amount		
A. *Horses & Horsekeep*							
1. Horses	2		185	00			
2. Oats	29,907	lbs.	598	14			
3. Hay	23,406	lbs.	152	14			
4. Other Feed			140	41			
5. Medicine			2	38			
6. Stable Fitting & Supplies			35	23			
7. Harness			12	32			
8. Shoes, &c.			4	10			
9. Vehicles			2	92	1132	64	
B. *Timber, &c., &c.*							

Wherever it is possible, or useful, the quantities are recorded —see the sample figures on the sheet above. The whole of the records are kept by the warehouse clerk, who sends each morning to the manager an invoice of material delivered the previous day from the warehouse to the colliery. The invoice is arranged in the same order as the standard index and summary, and the cost of each main item is calculated for the purposes of the daily approximate cost-sheet. From the monthly summary the "material" section of the monthly cost-sheet (Form 1*b*) is prepared. The system of requisitions for material and the ordering of material do not call for mention in this paper.

The Approximate Daily Cost-Sheet (*Form* 1*a*).—Where one colliery only is concerned, Form 2 will be a sufficient guide to the trend of the daily costs, although it will be found useful to design a summary which will show the cumulative or progressive cost to date. The daily sheet alone is disturbed by the fluctuations attendant on colliery operations, and it is necessary to have a progressive cost in order to compare the results to date with previous periods. The form of such a sheet will vary with individual circumstances, but it is so simple a modification of Form 2 that it does not need to be illustrated here.

Where a number of collieries are directed from a central office it will be found necessary to keep a condensation of the daily costs in the office of the Chief Executive. It will be found sufficient to record merely the output, and the force of workmen and expenditure under the main headings of surface labour, underground labour, mining coal, and material. This will be worked up into a progressive cost as previously mentioned, and will afford sufficient information to enable the Chief, or his assistants, to follow the trend of costs, and if the indications point to conditions needing investigation or remedy, the colliery itself can be visited, and there the components of the cost expenditure can be followed in complete detail. The importance of daily cost returns is elsewhere urged.

Monthly Cost-Sheet (*Form* 1*b*).—The final cost-sheet is prepared from the two monthly summaries, plus any inter-departmental credits or debits. The totals, of course, require to agree with the total pay-roll disbursements and the warehouse accounts, but otherwise the cost-sheet does not enter into the book-keeping

work. The figures on the final sheet are accurate, and they constitute the permanent record. When this sheet is issued, it supersedes the approximate sheets which may then be destroyed. All tabulations and comparisons are based on the final sheet. The form of this sheet will vary with localities, and differing methods of coal extraction, but the general arrangement will be essentially the same. The form of monthly cost-sheet which would be the final result of the several steps enumerated is as under:—

MONTHLY STATEMENT OF COST OF COAL.

Output.....Tons. Month of.....19.....

Classification	Force	Amount	Per Ton
Labour—			
1. Foreman & Clerks			
2. Screening & Loading			
3. Enginemen & Firemen			
4. Mechanics			
5. Other Surface Labour			
Total Surface Labour			
6. Officials			
7. Haulage Men			
8. Ventilation			
9. Roadmakers & Timbermen			
10. Pumpmen			
11. Miscellaneous Labour			
Total U. G. Labour			
12. Hand Mining			
13. Machine Mining			
Total Mining Coal			
Total Labor			
Material—			
A. Horses and Keep			
B. Timber			
C. Haulage & Hoisting			
D. Track Material			
E. Boiler Material			
F. Pumps & Piping			
G. Machinery & Power Transmission			
H. Mining Tools & Supplies			
J. Pit Tubs			
K. Oils			
L. General Stores			
M. Coal			
Total Material			
Administration			
General Charges			
Grand Total			

Dealing with the more technical data mentioned in division "B" at the beginning of this paper,—there are numerous expenditures which may profitably be tabulated and watched in addition to their inclusion in the cost-sheet. Some of these are as follows:—

Horses and the cost of horse keep.—A register of the horses should be kept, in which are noted full descriptive particulars of each horse; the date of purchase and the price paid; the date the horse went out of service and for what reason; if sold, the amount received, and if killed or dead the cause of same. Tabulations may be made showing the wastage in horses, and the fluctuations in purchase and selling prices. The item connected with horses, however, which needs most careful attention is the cost of feed and attendance; and the item of provender should be particularly watched, as it is one that is open to wastage or mis-use and to misappropriation.

Oil consumption.—This record will include all engine oils (various grades), black oils, tub and car grease, cotton waste, wipers, etc. It will be found that the tabulation of the consumption of oils and comparisons with previous records, or the records of other collieries, tends greatly to economy in the use of material where waste often takes place.

Such items of material as hand-tools, powder, rails, etc., repay watching; and a careful underground official, with accurate data to help him, can put a stop to loss which often occurs through material of this kind becoming buried or lost by careless men and through theft.

Records of timber used will afford an index for future purchases, and assistance in figuring on the cost of varying systems of coal extraction.

A dissection should be kept showing the number of tons of coal produced in the various stages of extraction, the relation between narrow work, that is development work, and rooms and pillars; all materials of considerable importance to the Superintendent of Mines. There are other main items such as coal and water, pit tubs, safety lamps, etc., which will at once suggest themselves to persons familiar with mine data. It will be found useful to keep tabulations of the production of coal per class of employee, per mine machine, and in the different stages of coal extraction.

It will be found conducive to the harmonious working of a colliery if the officials will pay close attention to the wages earned by their men. The average earnings of contract men should be calculated and carried out on the pay-roll, and the manager should

make it a subject for inquiry when a workman is credited with wages which are apparently either too large or too small, for both conditions show that something is wrong. The tabulation of average earnings is particularly necessary where contract rates are largely used in the payment of work that is generally rated on a day-wage basis.

It will be found useful to pay particular attention to the force of workmen on idle days and Sundays. This is important if the mines are not working regularly. It will sometimes be found for example that a large piece of machinery such as a compressor may be operated for the running of one small pump. In a case like this it is more economical to stop the pump, and provide sufficient lodgement room for the water. Similar cases will occur to those familiar with colliery operations, and it will be found useful to keep just as strict a watch on Sunday and "idle-day" costs as on the operating costs.

At certain seasons of the year there are disturbing factors in colliery costs, particularly in the material,—such as extraordinary repairs, new ropes, new pit tubs, large batches of horses, etc. It is a moot question whether it is better to let these large expenditures show naturally on the cost sheet as they are expended, or to have a system of suspense items by which these periodically recurring expenditures are equalized over the year's work, and the preference is largely a matter of opinion.

Cost data and comparative records of the kind this paper has dealt with, afford scope for graphical plotting, and a really wonderful mass of information can by this method be collected into a small compass for the use of a Chief Executive. A graphic record shows at a glance the tendency or the trend of any particular item of data, and it forms a very useful guide to men whose duties are so multifarious that they can only afford time to take up those matters which appear most pressing. To do full justice to this subject would necessitate a paper in itself, and it is merely mentioned in passing.

The clerical work of calculation of costs, percentages and averages is much lightened by the use of a slide-rule. A 20-inch rule will give as many decimal points as are likely to be required in work of this nature.

THE ALTERATION OF VEGETABLE MATTER INTO COAL.

By D. B. Dowling, Ottawa, Ont.

The original composition of coal has for various reasons been assigned to accumulations from plant life. This material contains a much smaller percentage of carbon and more oxygen than coal, but microscopic examinations of the latter show it is partly composed of particles of cellular matter among which plant spores are often detected. The lower grade coals and those generally least altered are so manifestly made up of charred pieces of wood that their derivation from plant remains is beyond question and it is only for portions of seams showing no structure that other sources or origins have been sought. Enrichment from petroleum deposits has been suggested to account for certain bituminous appearances and behaviour when burned.

If we assume that this bitumen has resulted from the decay of plant or animal life we need only consider the possible method of decay; but if the bitumen is assumed to have originated in the deeper parts of the earth the manner of impregnation must be considered, and, to account for which is far more difficult. It is hardly necessary to cite more than a few cases, where bitumen has been proven to be of organic origin, in order to establish the probability of the bitumen of the fatty coal being also organic. The Trinidad pitch containing small percentages of nitrogen was discovered by Prof. Rupert Jones to contain remains of *Nummulinae* and *Orbitædes** showing a possible animal origin for this material. If a derivation from plant remains is assumed it has been claimed that only from the richer parts of these and mainly from the more recent species, could come the bitumen of the

* Qua. Jour. Geol. Soc. XIII. 1866, p. 592.

fatty coals. This argument can hardly be of great weight since most of the fatty coals are of remote age, and of the period of the simpler plant forms.

The researches of Bertrand and Renault* on the bogheads of Autun and oil shales of New South Wales, lead to the supposition that *Algae* form the major portion of the original material. The aquatic plants were described and named and one of the species subsequently recognized in the Scotch oil shale.

For more modern examples it may be noted that in the Sardinia salt marshes as well as in the sands of the Sound, Sweden, it has been observed that decaying sea-weeds are really forming oily substances. The possibility of minute animal remains forming a part of the decaying mass has also been discussed, but generally in connection with the possible formation of petroleum. For certain fatty coals, therefore, we conclude that although minute animal remains may possibly have contributed, marine plants are more likely to have composed the major portion of the mass.

The behaviour of coals for a certain carbon content is found to depend mainly on the percentage of hydrogen they contain. Those with hydrogen above the normal are free burning, long flame, coking or in general fatty, while those with hydrogen below the normal are short flame or dry coals. The question of the derivation by alteration of the different varieties of coal from a common constituent, namely woody fibre, is one on which very little has been written. Some considerations may now be presented bearing on the possible conditions that may have influenced its transformation and hence caused variations in the resulting coal. These may be considered under three heads namely:—

(1). Variations in original composition.

(2). Duration and character of decay.

(3). Amount and kind of alteration due to dynamic and geologic influences.

Composition of Original Material.

It is unsafe to say that we know the composition of the plants of the Carboniferous, Permian or Jurassic age that were altered to coal; but we may accept from naturalists a fairly common law,

*Bull. Soc. Linn, Normand, 4 VIII, 1894, p. 323.

that in both plant and animal life low types endure long and that, into however many varieties either may change, some still preserve traces of the original. Thus for plants, we can assume that forms more nearly approaching the early types in habit and structure should also be nearest to them in composition. Selecting, then, the ferns and mosses as being primitive forms we find that they, in composition, are very little different from other plants, resembling in the main the average woody tissue.

Differences in chemical composition between the various early forms of plants can therefore have had very little effect in influencing the final composition of coal. There are, however, variations in composition and character in the plant itself that may indicate possibilities of different rates of decay and consequent changes. Leaves, branches, bark, wood, and roots show slight variations one from the other. Generally speaking leaves have high hydrogen and low carbon percentages, while bark and wood have high carbon and low hydrogen content. This seems to indicate that the herbaceous plants would be high in hydrogen compared with harder varieties having woody tissue, hence there is a possibility that the smaller plants might form deposits which would originally differ in composition from other masses. When, however, the vegetation was of a mixed character (although there may have been original differences in the composition of the different plants, they were so mingled together in the mass as to not affect the coal except in appearance. The soft vegetation by its easy disintegration loses its organic structure and assumes the appearance of a jelly-like mass that probably constitutes the material which in many cases forms the bright coals or the bright streaks in dull varieties, such as the lower cretaceous coals of the Rocky Mountains. The partly obliterated cellular tissue remnants of the more resistant parts of the vegetation, is found generally in the duller parts of the coal and though originally this was as low in ash as the softer parts it now probably contains most of the ash originally in the whole mass, since the jellied portion has no doubt lost part of its original ash by gravitation through to the firmer material beneath. The chemical variations in coal, due to original composition, seem to be influenced greatly by the physical character of the original mass. The softer vegetation seems to contain a lower percentage of carbon and is easily macer-

ated and consequently more quickly subjected to the alterations of the decaying stage.

Process of Decay.

The initial change in the vegetal mass follows immediately after the death of the plant. The vital energy of the cells that throughout the living period was expended on the absorbing of carbon compounds, is then relaxed and compounds of carbon and oxygen, as well as others, including volatile hydrocarbons, are quickly formed. Should there be a general loss of carbon dioxide, the effect, that is if the process is maintained for a long period, will be a general raising of the hydrogen and carbon percentage of the remaining mass. The hydrogen, however, when it is in excess is likely to be set free and to take with it some carbon. This means the loss of both hydrogen and carbon, generally in the form of marsh gas, until they are reduced again to a point of greater stability. Hence the decaying stage, appears to induce the liberation of carbon dioxide to a point at which the mass remaining is high in hydrocarbons and then, the hydrocarbons, being unstable, give off volatile gases until stability is arrived at. Variations, then, in the resulting coal may depend largely upon the period or stage at which the process of decay was stopped.

Bacteriological fermentation that seems to be present in all decay, apparently aids the production of carbonic acid, at the same time forming more stable hydrocarbon compounds in the mass. This, if proven, means that fermentation directly raises the hydrogen and carbon percentages, possibly by forming from the complex mass definite compounds between the hydrogen and carbon and allowing compounds of oxygen and carbon to escape.

The assimilation of hydrocarbons is common to both plant and animal life. In animal life large percentages of nitrogen are stored in the body cells, while in plants a much smaller amount is required. In the forms of life found in ferments a very small nitrogen content is required, so that one function of fermentation seems to be the liberation of nitrogen from the mass as well as of carbonic acid gas. Humic acid, which arrests the process, is also formed; but if the bog or bed be not stagnant, this is drained away and the fermentation continued to the stage where volatile hydro-

carbons cannot be retained and marsh gas is given off. The point at which fermentation is arrested no doubt determines in great measure the chemical composition of the ultimate product. The possible history of the process of the chemical change may be summed up as follows:—

During the fermentation stage the loss of CO_2 raises the percentage of hydrogen and carbon; then marsh gas is lost and these two percentages decrease. This process may be repeated many times, but cannot continue indefinitely; entombment under other deposits will evidently check it and the hydrogen percentage of the mass may vary from a stable condition with low hydrogen to an unstable one with high hydrogen percentage.

Experiments on fermentation have been undertaken with the object of tracing the origin of natural gas. The composition of the gas given off has been carefully noted and, in all the published results, the tendency has been first toward a production of CO_2 with nitrogen in small amount and, toward the end of the experiment, the production of CH_4. The results of several of these experiments may be here cited.

Substance fermented:—

Pure celulose $C_6 H_{10} O_5$.
Experimenter. Tappeiner.*

Gas evolved.	at beginning	at end.
CO_2 \ H_2S /	85·48	76·98
H	0·0	0·0
CH_4	11·86	23·01
N	2·73	0·0
	100·07	99·99

In another experiment given by "Hoppe-Seyler" the gas expelled from the marsh gas fermentation of cellulose was:—

CO_2.	50·
CH_4.	45·
H.	4·

* Ber. I. Chem. Geo. 1883 Part. 16. pp. 122 & 1734.

In the decay of seaweed Phillips* gives results from seaweed from Santa Barbara, which was left to decay in water. The gases given off at three periods were as under:—

	1st	2nd	3rd
CO_2	18·23	32·47	53·44
CH_4	0·30	0·28	0·08
H	62·24	48·97	42·02
N	19·23	18·28	4·46
	100·00	100·00	100·00

An experiment by Franklin and Jordan, gives, for† grass left to decay under water, an evolution, in 3 days of the following:—

CO_2	84·63
O	0·13
H	6·90
Combustible gases	2·51
N	5·83

The change indicated in the case of seaweed is an early liberation of large quantities of hydrogen and nitrogen—a similar result to that which might be expected from animal remains and one suggesting that there is not as wide a difference in composition between low types of aquatic plants and animals as one might suppose. The liberation of hydrogen might also at first be partly due to decomposition of water in the oxidation of the tissue. In the later stages this hydrogen loss is reduced and the production of carbon dioxide rises.

In the case of the decomposition of grass under water, evolution of carbon dioxide is the principal result, although free hydrogen seems to be present and tends to reduce the hydrogen content of the resultant mass. This loss of hydrogen would probably not be maintained for any length of time, and the process of decay would actually result in an increase in the carbon and decrease of oxygen percentage.

* The Am. Chem. Journal, 1894, p. 27.
† Journal Chem. Soc., 43, 295 (1883).

The simple heating of vegetable matter such as hay, manure, &c., indicates an alteration comparable to a slow combustion. That the alteration results in the increase of carbon has been demonstrated by Mr. A. Straham* in analyses of the fresh material and the darkened compact masses from hay ricks. The analyses for ash free material are:—

	Fresh hay.	Darkened hay.
Carbon	48·96	51·61
Hydrogen	6·33	5·88
Oxygen	42·41	40·50
Nitrogen	2·30	2·01

The increase in ash in the two samples may indicate the amount of loss, and on this basis it may have been as high as 18 per cent., distributed as follows:—

Carbon	6·63
Hydrogen	1·51
Oxygen	9·29
Nitrogen	·65
	18·08

The form in which this loss occurred was probably gaseous. Of the ordinary combinations the following will satisfy the above proportions.

Ammonia	0·79
Carbon dioxide	11·01
Marsh gas	4·84
Water	1·44
	18·08

If free hydrogen or nitrogen were liberated these amounts would be slightly altered, but they no doubt represent in a general way the conditions that were formed.

* Memoir Geol. Survey. England and Wales, "The Coals of South Wales."

In a bed of mixed vegetable material the softer parts, which generally are lower in carbon, suffer both maceration and fermentation with a consequent increase in their carbon content while the harder parts decompose more slowly; hence a uniform percentage of carbon is soon attained in the mass. Coals of a uniform, bright fracture are evidently from homogeneous soft material in which the maceration was complete before entombment. In the bright coals frequently are found beds in which the ash is very low. In these cases it may be that the jelly mass had been derived by settlement in basins, from the drainage of swamps or bogs, the transporting waters carrying the ash particles but short distances compared with the distance to which the gelosic material could be transported.

Aquatic plants are, as a rule, easily disintegrated and microscopic *algæ* are especially so. The inference that these materials would rapidly decay and reach a higher stage of alteration before entombment is natural, so that the high hydrogen of cannel coal might be accounted for by ascribing its derivation to aquatic vegetation, with, no doubt, microscopic animal life associated with it.

If cannel coals are of aquatic plant and animal origin they would be expected to occur largely in the marginal continental coal areas as well as occasionally in inland lake basins; and as aquatic plants preceded land forms it is reasonable to expect that the majority of these beds of cannel coal would be found in the early coal measures rather than later on. In fact, the sequence should be (1) beds formed of aquatic life, probably both animal and plant—the beds enriched from animal remains forming oil shales. (2) Beds in which aquatic plants predominate, forming cannel coals, and (3) beds in which land plants predominate, forming the majority of the coals.

This sequence is borne out, in general, in the actual coal fields. The shales, generally called oil shales, have in some cases been found to contain minute animal remains and are mostly early or pre-Carboniferous. The cannel and boghead coals are early Carboniferous as well as upper Carboniferous, while the true coals, of land plant origin, follow through the Carboniferous and during later times.

Alteration Due to Dynamic and Geologic Influences.

This phase of the alteration of coals was the subject of a paper read at the last annual meeting and published in Vol. XII. The general scope of the paper may be here summarized.

A bed of decaying vegetable matter in the course of time may be submerged and detrital matter deposited above it by crustal movements or by freshets. If the crustal movement is in the nature of oscillations, repeated beds of coal mark the period above or near sea level. These variations in the case of inland basins may result from crustal movements or climatic changes. The covering detrital matter gradually becomes a load by which the mass is compressed. This compression may be intensified by crustal movements or, if sunk below the surface by the load, a rise in temperature may result. The influence, then, at work on the carbonaceous material is pressure and, possibly, heat. The effect of heat is toward driving off hydro-carbon gases, and a consequent loss of material. The effect of pressure, beside solidifying the mass, is in the course of time, toward a slow change, which increases the carbon, without loss of hydrocarbon compounds and in general favouring the formation of water and carbonic acid.

The alterations in the vicinity of zones of fracture or where the covering beds are porous probably entails the loss of hydrocarbon gases and hence a more rapid rate of alteration. Thus beds confined between close grained deposits generally suffer slow alteration with a minimum loss of carbon, while beds confined between pervious strata are rapidly altered to more stable compounds.

The general alteration of coal beds from the peat stage is possibly due to a combination of heat and pressure and in the history of any seam may vary between wide limits. Portions may remain through long periods without much alteration, even if closely confined and subject to pressure, while other parts, to which heat has been applied, may undergo a more rapid alteration. Should opportunity be given for the escape of hydrocarbon gases the alteration may be carried still farther. The distillation which results from the presence of intrusive masses is an instance of the latter class and resembles almost a coking process. These coals

that have suffered rapid alteration quickly lose their hydrogen and become non-coking.

Variations in coals, then, may be due to:—

1. Original composition, in which the softer varieties of vegetation contain an initial high hydrogen percentage and are rapidly desiccated and prepared for fermentation and subsequent changes.

2. Duration and character of decay, in which the initial loss of carbon dioxide may be prolonged by fermentation, thereby raising the hydrogen to the critical point at which hydrocarbon is lost, the character of the ultimate product depending mainly on the stage reached in the process.

3. Alteration due to dynamic and geologic influences, in which hydrogen is probably lost in the rapid forms of alteration, and conserved in the slower process, in which static pressure is the principal influence.

THE GALT COAL FIELD, ALBERTA.

BY W. D. L. HARDIE.

(Western Branch Meeting, Nelson, B. C., September, 1909)

The Galt coal field may be said to extend from the confluence of the St. Mary and Belly rivers to a point where the waters of the Bow and Belly rivers join to form the South Saskatchewan river. Apparently the workable and merchantable coal seams spread out about two miles on each side of the river, sufficient prospecting and development work having been done to justify this conclusion so far as the right hand or south bank of the river is concerned; but on the left bank of Belly river below Lethbridge the facts are not decisively known, since very little prospecting and practically no development have been undertaken. The prospecting on the left hand side of the river at and near Lethbridge indicates that the area on that side may exceed the two-mile limit given above.

By merchantable coal is meant a product which will be acceptable in competition with other coals placed on the western market, which extends from Winnipeg to the Boundary district in British Columbia.

The limit of area of merchantable coal on each side of the river is defined by a line forming an irregular curve that does not, however, conform with the sinuosities of the river channel. The indications, meanwhile, are that at the edges of the two-mile limit referred to the coal begins to gradate from good or merchantable coal, to bone coal, to "black jack" (thinly laminated alternating layers of coal and shale), to pure shale, and finally to clay. At some points along the river this process extends a long distance out; but at others it is not markedly so.

Throughout the merchantable area the coal averages four feet in thickness. It is, however, thickest in the neighbourhood of Lethbridge, where it averages 52 inches. There are two distinct seams, as shown by the accompanying section. The analyses of these coals are also added to show their character. This coal is fairly representative of the Galt field:—

ANALYSES

	Moisture	Vol.	Carbon.	Ash.	Spec. Gravity.
No. 1. . . .	8·66	29·44	50.75	11·15	1·34
No. 2. . . .	7·25	31·41	50·89	10·45	1·41
Average. .	7·75	30·72	50·82	10·71	

The two seams are almost invariably separated by a streak, (varying in thickness from one to six inches) either of fireclay or of bone coal. The bone coal when replacing the fireclay is usually from an inch to six inches in thickness. These partings frequently give place to one another in comparatively short distances. In the mines at Lethbridge they often alternate again and again in the length of a room, which is 250 feet.

Assuming the coal extends for two miles only on each side of the river; that it is four feet thick, and the distance from St. Mary to the Grand Forks is 75 miles, the area will produce, making liberal allowances for loss of coal in mining, 1,233,378,000 tons.

In addition to this main area of mineable coal beds, others may be expected, since the beds constituting the field extend north and south through the province; but it is not thought that the quality of the coal will be as good as in the Lethbridge area. The extension south passes near Milk river station on the Alberta Railway and Irrigation Company's railway line near the southern boundary of the province. Thin seams of coal have been found in this vicinity, and one some distance down Milk river near Dead Horse coulee has a thickness of 3 feet 6 inches. Northward the measures of this horizon have been traced to near Vegreville on the Canadian Northern railway. Coal seams are occasionally found

in it; but are not always of workable thickness. The part of this extension that should be the most valuable reaches to Red Deer river. On Little Bow river, coal of this formation should be found in township 12; and on Bow river the seams at Grassy island near Bow Centre are of the same age. Four seams here outcrop in the river banks. A seam with a reported thickness of 5 feet 7 inches is about to be mined. On Red Deer river above Hunting Hill three seams in these beds are known and one of them having a thickness of 3 feet 6 inches may be mineable.

It might be remarked, in passing, that, so far as observed by the writer, all the coal seams on the prairies of Western Canada have their location on large streams or rivers.

Anent the geological age of the Galt coal field, there appears to be a divergence of opinion, some attributing it to late Cretaceous while others allocate it to the Tertiary. There is a well defined bed of marine fossils overlying the uppermost little seam shown in the accompanying drawing, representing the lower part of the carefully recorded section made when sinking the Alberta Railway and Irrigation Company's shafts Nos. 5 and 6 (Galt colliery).

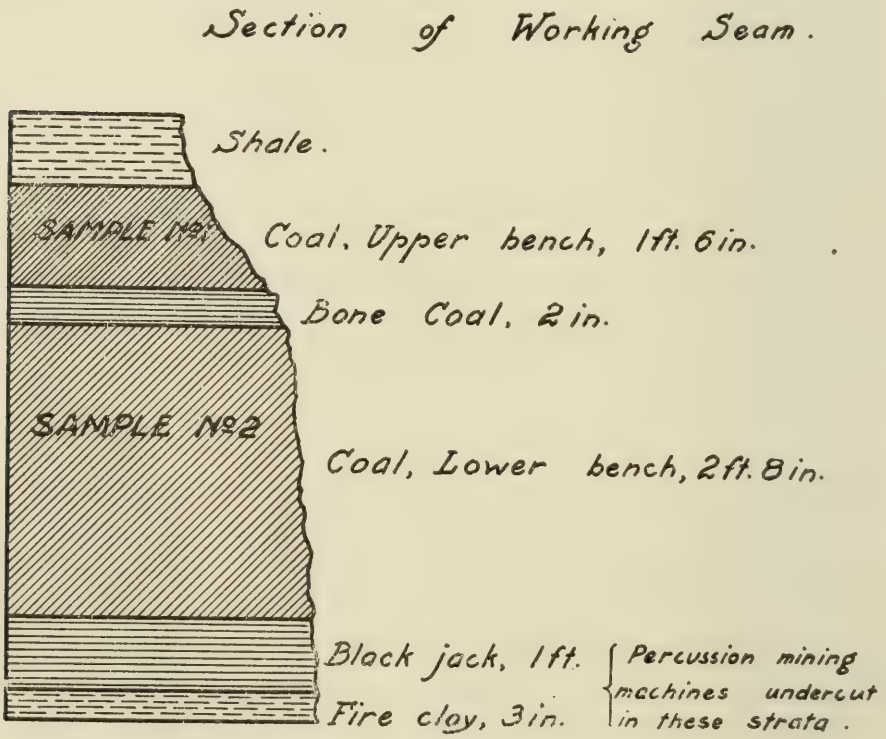


FIG. I.

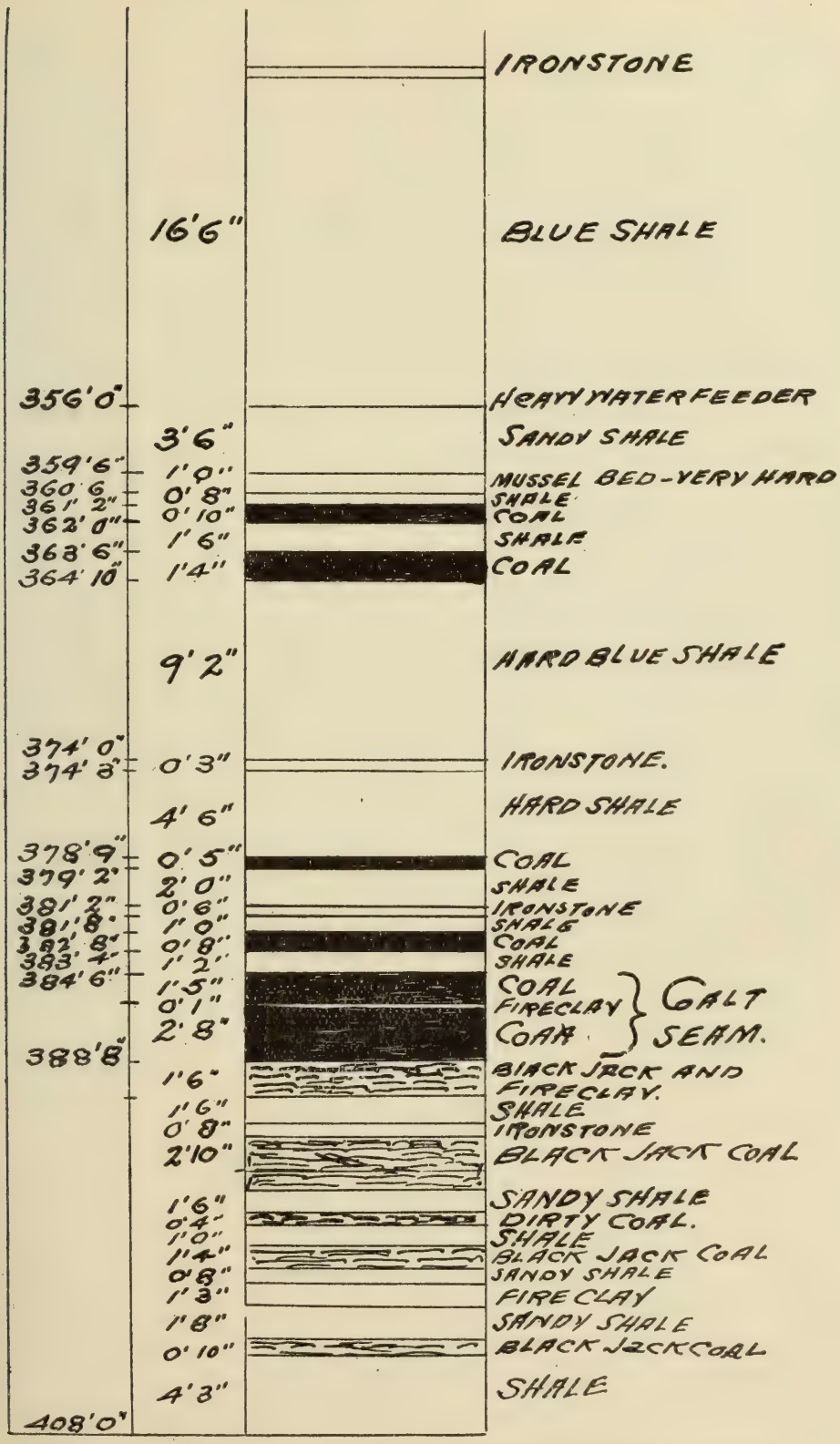


FIG. II. Lower section of Shafts Nos. 5 and 6, Galt Colliery.

During the sinking of the two shafts referred to, a careful watch was maintained for fossils; but apart from the mussel bed only clay-stone nodules and several *corbicula fracta* were found, the former well up in the clay and the latter well down in the shale, but above the mussel bed. This fossil would indicate that the seam belongs to the Laramie or transition epoch, between the Cretaceous and Tertiary.

Meanwhile the coal mining plants at present in operation in the Galt field are capable of providing the market with from 4,000 to 5,000 tons per day; while other plants are either under construction or in contemplation. Since this coal is now used for domestic purposes chiefly, the active demand is restricted to from six to eight months in the year. It is not intended, however, that the idea shall be conveyed that the coal is not a good steam coal. For many years the Galt mines were practically the only producing colleries on the prairies, and their coal from the time of the construction of the Canadian Pacific railway until the Crow's Nest branch was built and the steam and coking coal areas of the Crow's Nest Pass opened—some nine years ago—was largely used by the Canadian Pacific Railway Company for fuel on locomotives and at stationary plants. The coal, as the analyses show, is comparatively low in carbon, while the Crow's Nest Pass coal is high in that constituent. The proximate analyses here given do not show, however, the percentage of hydrogen in the volatile matter, which is quite high; especially in the coal from the lower bench or seam. The Galt coal in general burns very freely; that from the lower bench particularly so, and is consequently held in high esteem by consumers.

DISCUSSION.

MR. D. B. DOWLING (Communicated to the Secretary).—Concerning the geological age of the measures from which the Galt coal is mined there has been some controversy. In the report of the Boundary Commission, 1875, these beds were included in the "Lignite Tertiary," of about the horizon of the Laramie. Later explorations revealed the fact that they were below the Pierre

shales, a marine bed in the Cretaceous, and therefore below the Laramie. In Montana, similar rocks on Judith river were found to lie above shales containing Pierre fossils; hence the original judgment was evidently a mistaken one. The point remained in dispute (or rather the Cretaceous age of the Belly river beds was questioned) until in 1903 Messrs. Stanton and Hatcher of the United States Geological Survey traced the formation from the Judith river to the beds in Alberta and found that they were one and the same, and also that Pierre shales were both below and above the apparent Laramie; so that its position as determined by the Canadian geologists was substantially correct.

Hence the formation at Lethbridge represents a shallowing of the Cretaceous sea forming land areas in places. These land areas were submerged before the end of Cretaceous times and the deposits which covered them during this marine invasion, separate the Belly river rocks from the Laramie above—two formations that are remarkably similar and have fossils that can hardly be distinguished. The Lethbridge coal bearing rocks are therefore below the very similar ones bearing coal at Crowfoot Crossing on the Bow river, or the rocks higher up the St. Mary river.

SPONTANEOUS COMBUSTION OF COAL.

By Edgar Stansfield, M.Sc., McGill University, Montreal.

Rather more than three years ago, Dr. J. B. Porter was commissioned to conduct an extensive series of tests on Canadian coal for the Dominion Government. This investigation, which has been carried out at McGill University, and for which the writer has been employed as chief chemist, is now drawing to a close. Our attention has been repeatedly drawn during its progress, to the allied problems of the weathering and spontaneous combustion of coal; but it was quite impossible to include more than a few observations on the first of these problems in the investigation, although its scope, as originally planned, was from time to time enlarged.

The deterioration of stored coal is a very serious matter to all large dealers and consumers, and fuller and more definite information on the subject is urgently needed.

A study of the extensive literature bearing upon spontaneous combustion has shown that although much has been accomplished, a great deal more remains to be done. This literature is not easily accessible and although there have been excellent summaries published, these chiefly refer to the question of the shipment of coal cargoes, so that there does seem a need for a statement as to the known facts and present theories with especial reference to land storage. It is this need that the present paper is an attempt to fulfil.

The writer wishes to acknowledge his great indebtedness in the writing of the paper and for his diagrams to the Report of the New South Wales Royal Commission (1897), and to a paper by Prof. R. Threlfall "The Spontaneous Heating of Coal Particularly During Shipment" (J. Soc. Chem. Indust. July 31st, 1909, pp. 759-773). The following papers have also been freely made use of: "The Spontaneous Ignition of Coal and its Prevention," by Prof. Vivian B. Lewes (J. Soc. of Arts, Vol. 40, 1892, pp. 352-365), and "The Spontaneous Combustion of Coal on Board Ship," by Commander W.F. Caborne, C.B., R.N.R., (J. Roy. United Services Inst., XLVI, p. 285 and reprinted in The Mining Journal LXXII, 1902, p. 124 et seq.).

Spontaneous combustion of coal may be divided into three classes, fires in the mines, fires in ships and fires in land storage. All these may at times be of very grave importance; they have all three caused the loss of incalculable sums of money and the first two have resulted in the loss of very many lives.

A few examples will illustrate the importance of the subject :

At the Hamstead Colliery in South Staffordshire, England, is worked what is known as the "Thick Coal Seam," there about 20 feet thick. This seam is not gassy; but is extremely liable to fire spontaneously. There were no less than 200 fires in the 20,000 feet of return airways in 1895, and 250 in 1896. In November 1898, a fire broke out so suddenly and acquired such magnitude that the mine had to be closed, and this in spite of elaborate precautions and almost constant inspection.

In the nine years between 1873 and 1883, fifty-seven boats leaving British ports with coal cargoes are known to have been lost owing to spontaneous combustion. Three hundred and twenty eight others disappeared during the same time and we can only guess at their fate. These figures only refer to vessels actually lost. In 1874 alone, seventy cargoes either fired or heated.

During the last two or three years the writer has seen or heard of several spontaneous fires of both Cape Breton and Pennsylvanian coal stored in Montreal. The following is an extract from a letter received by Dr. Porter from the President of an Ontario firm using Pennsylvanian slack coal: "With reference to the trouble with our coal pile here, I am sorry to say that the conditions got very much worse after I wrote you on September 24th, and I found that the greater part of the dump was beginning to heat. . . . . The only lot of coal that we have that does not appear to be more or less hot is one comparatively small pile that stands by itself. . . I must say our experience this year has discouraged me from trying to handle a large dump of slack coal, which is very unfortunate, as it is much the cheapest and most satisfactory way for us to handle our coal, as we have our own boats, and plenty of space to pile it; whereas, in the winter, there is always more or less trouble, in bad weather, in getting a regular supply of cars."

The above cases are all of more or less open combustion; but, as will be shown later, all coal, even though not perceptibly warm, is in a state of combustion for at any rate many months after it is mined, and this combustion of course means deterioration.

Trouble with coal cargoes at sea has materially decreased of recent years, largely due to decrease of length of voyages and increase of knowledge; but on land, especially in Canada, trouble from the heating of coal is probably on the increase.

In all the great manufacturing countries, large concerns are more and more compelled to have large reserves of coal on hand. The admiralties carry coal stocks as a preparation for war, manufacturing firms to reduce the dislocation caused by strikes at the mines or in the carrying trades, or merely to tide over fluctuations in the price or supply of the coal they require.

Here in Canada the nature of our winter almost compels the storage of very large quantities of coal, especially at such places as Montreal, where coal can be obtained comparatively cheap in summer by water; but where the railroad freight necessary in winter renders the price almost prohibitive.

One railway company stacks from 200,000 to 250,000 tons of coal in Montreal alone each year, and the constant expense and trouble to which it is put to avoid fires, to say nothing of the loss due to the deterioration of the coal, is enormous. Every railway company, every coal dealer, and every large consumer has also to store coal.

Enough has been said to show the great importance of the subject under discussion and also to show that any information that would in future result in reducing the losses on stored coal, even if only by one cent a ton, would be a valuable asset to the community.

The coal from the Hamstead Colliery referred to above, being extremely apt to fire spontaneously, forms a good starting point in studying the question. Messrs. Haldane and Meachem have brought forward a lot of interesting information in this connection.*

They state that the mean temperature of the air at the foot of the shaft in the intake airway is 60°F. and in the return airway is 77°F. The natural temperature of the undisturbed strata at the level of the pit bottom is only 68°F., so that the whole of this rise in temperature of the air cannot be due to the natural

* "Observations on the Relation of Underground Temperature and Spontaneous Fires in the Coal to Oxidation and to the Causes which Favour it," by J. S. Haldane, M.D., F.R.S., and F. G. Meachem, M.I.M.E. (Trans. Inst. M.E., 1898, Vol. XVI, pp. 457-492.)

heat in the strata, on the contrary, the strata is being gradually heated from the mine. "The coal behind an exposed surface gradually rises in temperature, month by month, and year by year. Thus at two places in the side of a main road, where the temperature at the end of 10 foot boreholes was 66°F. in 1894 it had risen to 83°F. and 90°F. in 1898."

They calculate that every cubic foot of air passed through, removes one British Thermal Unit of heat from the mine; also that of this quantity of heat at the outside 7% could be accounted for by the presence of horses, men, and burning candles, 10% by the settling of the superincumbent strata, and 2% by the friction of the air. This leaves over 80% unaccounted for. "The only other possible source of heat in the mine is the chemical action of the air on the exposed coal and other material."

Temperatures were taken at different points in the airways and analyses made of samples of air taken at the same points. The analyses show that as the air passes through the pit it steadily looses oxygen and gains carbon dioxide, the average loss being 3·13 times the gain (in most collieries this ratio is said to be about 1·6). The following table, Table I, clearly shows the intimate relation existing between the rise in temperature and the decrease in oxygen :

TABLE I.

Temperature	Decrease in Oxygen.	Temperature.	Decrease in Oxygen.
55° F.	0·00%	78° F.	0·36%
71	0·16	80	0·77
73	0·25	83	0·88
74	0·37	83	1·70

The temperature of the air circulated through the mine does not steadily rise as it proceeds, because as it returns from the working face it is cooled from time to time by leaks from the intake airway, so that the foot of the upcast shaft is by no means the hottest place in the mine.

Haldane and Meachem have also made laboratory experiments on this coal in which they filled a quart sized flask with roughly powdered coal and left the flask sealed up in connection with a mercury pressure guage. They found that the pressure of the air in the flask steadily decreased for some time (unless the coal in the flask was very fresh, in which case the pressure first rises owing

to the evolution of hydrocarbons), and an analysis of the residual gas then showed it to be almost pure nitrogen.

The following figures, Table II, show the course of such an experiment. The coal, which had been lying in lumps in the laboratory for three months after being mined, was crushed in a mortar and left lying in a thin layer (to allow any gas to escape) for two hours before putting into the flask. The temperature of the flask was about 54°F; the pressure readings were corrected for changes of temperature and barometric pressure.

TABLE II.

Time since closing Flask.	Negative Pressure of Mercury.	Time since closing Flask.	Negative pressure of Mercury.
1 hour	0·15 inches	4 days	5·05 inches
5 hours	0·65 "	5 "	5·45 "
12 "	1·25	6 "	5·75 "
24 "	2·00 "	7 "	6·00 "
36 "	2·80 "	9 "	6·10 "
48 "	3·40 "	11 "	6·10 "
56 "	3·85 "	24 "	6·00 "
72 "	4·30 "	6 months	5·85 "

The analysis of the gas left in the flask at the end is shown in Table III.

TABLE III.

Oxygen	0·07%
Carbon Dioxide	1·28
Methane	0·65
Carbon monoxide	0·04
Nitrogen	97·96

This experiment shows, what had already been proved by Dr. Richters in 1868, that coal absorbs oxygen, presumably with the evolution of heat as it was shown above that the decrease of oxygen in the air in the mine was accompanied by a rise in temperature.

Another series of experiments performed by Haldane and Meachem consisted in passing air at a measured rate through a layer of coal in a flask. The flask being immersed in a water bath the temperature of which could be kept constant at any desired heat. Samples of the air that had passed through the coal were removed from time to time for analysis. Table IV shows the results of two such experiments :

TABLE IV.

Experiment I with 0·92 lbs of finely pounded coal, sent from the Pit 4 days previously and freshly pounded up.

Temperature of Bath.	Time since coal was pounded up.	Rate of Ventilation Per Hour.	Deficiency of Oxygen.	Carbon Dioxide Increased.	Methane and Carbon Monoxide.	Oxygen absorbed per ton of coal and per hour.
°F.	Hours.	Cub. Ft.	Per cent.	Per cent.	Per cent.	Cub. Ft.
59	2	0·091	1·10	0·07	0·290	2·45
59	5	0·131	0·72	0·02	—	2·30
59	8	0·080	1·00	0·05	—	1·95
60	20	0·114	0·46	0·04	—	1·26*
101	25	0·114	1·29	0·05	0·075	3·58
108	29	0.114	1.48	0.12	0.100	4·11
125	32	0·103	2.18	0.10	0.110	5.59

* Ventilation left on for 12 hours since last determination.

Experiment II with 2·7 lbs of pounded coal (same sample as used in last experiment) sent from the Pit 3 months previously and fragments pounded up a few hours before the experiment.

Temperature of Bath.	Rate of Ventilation per hour.	Deficiency of Oxygen.	Carbon Dioxide Increased.	Methane.	Carbon Monoxide.	Oxygen absorbed per ton of coal and per hour.
°F.	Cub. Ft.	Per cent.	Per cent.	Per cent.	Per cent.	Cub. Ft.
59	0·078	0·40	0·09	0·00	0·00	0·26
160	0·084	5·31	0·67	0·07	0·14	3·70

A sample of coal from another pit which had stood in lumps in the laboratory for about two years, was still found to absorb oxygen when pounded up.

Haldane and Meachem deduce the following important results from these experiments.

(1). The rate of absorption of oxygen by coal is proportional to the partial pressure of the oxygen present.

(2). The rate of absorption of oxygen is approximately doubled for every 30°F. rise in temperature.

(3). The rate of absorption of oxygen at any temperature decreases as time goes on; at 59°F. it falls to half value after 20 hours.

(4). The absorption of oxygen takes place on the surface, thus lump coal that had been exposed to the air for two years would absorb oxygen when fresh surface was exposed by crushing.

The experiments, by which the numerical values given are deduced, are open to criticism, but in any case these figures would probably vary with every different sample of coal. The general conclusions, however, are probably correct and bearing these in mind we can now go on to study the conditions existing in coal piles.

A pile of coal is in itself a very poor conductor of heat. This is shown by the fact that snow has been known to remain a whole year under a coal pile. The writer has heard of coal, stored during the winter in Cape Breton, brought up to Montreal during the spring or summer and rebanked, still having Cape Breton snow mixed with it when it was dug out of the pile. Again, it is customary to test the temperature of a coal pile by means of iron rods pushed down through the coal; it has not unfrequently happened that fire has been detected in a pile within three or four feet of a cool rod. We can therefore neglect the heat conductivity of the coal itself and assume that the only way in which heat generated in the pile can escape is by means of air currents. Again, on account of its low conductivity, after once a coal pile has been made the atmospheric temperature can have little effect except at the surface.

We will now consider a coal pile through which there is a slow circulation of air.

Then:—(1). Unless the surfaces exposed are already oxidised, oxygen will be absorbed from the air by the coal and heat will be evolved.

(2). Unless the heat of oxidation is carried away by the air current as fast as it is generated, the temperature of the coal will rise.

(3) As the temperature of the coal rises its rate of oxidation increases, that is heat is generated more rapidly, so that the hotter the coal is, the more rapidly it tends to get hotter still, unless some secondary effect comes into play keeping it cool. The increase of rate of oxidation with increase of temperature will vary with different coals and although the velocity of oxidation may not be doubled for every 30°F. rise, as is said to be the case with Hamstead coal, the rate of increase is undoubtedly rapid. In the

case of chemical reactions where the reacting substances are in intimate contact, as for example in solutions, the velocity of reaction approximately doubles for every 18°F. rise in temperature.

(4). As the temperature of the coal rises, the number of its constituents that can oxidize with noteworthy speed is increased.

(5). At any given temperature the rate of oxidation of the coal, that is, the rate of evolution of heat, will decrease as time goes on; this being due of course to the gradual completion of the oxidation of the readily oxidisable constituents of the coal.

(6). The higher temperature and the more rapid the oxidation, the greater the air current will have to be to supply the necessary oxygen. At the same time, the higher the temperature at any spot in a coal pile is above the rest of the pile and the outside air the more convection currents will be set up. A warm spot in a pile may thus cause its own cure by setting up convection currents sufficient, not only to supply the oxygen being absorbed, but, also, to carry away the heat faster than it is being generated and in this way to cool the spot.

Generally, after a coal pile has been built, the temperature at any place inside the pile slowly rises, the oxidation of the fresh coal being comparatively rapid; after a while, owing to the gradual completion of the oxidation of the surface exposed and to the cooling effect of the convection currents, the rise of temperature comes to an end and the coal begins to get cooler, ultimately reaching atmospheric temperature. Occasionally, however, the first rise in temperature will take the coal above what may be described as the critical temperature; the oxidation is then so rapid that the retarding and cooling influences are insufficient, and the coal goes on getting hotter and hotter until it is in open combustion.

A coal pile is more likely to catch fire if:—

(*a*). The coal is an easily oxidisable one.

(*b*). The surface of coal exposed is large.

(*c*). Air is supplied at a rate sufficiently fast to supply the required oxygen but no faster.

(*d*). The heat generated cannot readily escape, and

(*e*). The initial temperature is high.

We will now proceed to consider these conditions. (*a*) is confirmed by Prof. Fischer of Göttingen, who states that coals

which rapidly absorb bromine are those which are most liable to rapid oxidation and spontaneous ignition. He recommends, as a practical test, shaking one gram of the finely ground coal with 20c.c. of a half normal solution of bromine for five minutes. If the smell of bromine has then disappeared, the coal is liable to oxidise rapidly and is not a safe one to store. Prof. Lewes states that a coal that gains more than 2% in weight, when heated to 250° F. for three hours, is dangerous.

(*b*). As was shown before, the oxidation of the coal is a surface action, and the more surface there is exposed the more rapid is the action. Piles of lump coal rarely if ever catch fire; the danger is with run of mine or slack coal in which the surface exposed is so much larger in comparison with the weight. On shipboard, fires usually begin in the pile of broken coal formed under the hatches during loading. It is well known that cotton waste soaked in oil is liable to catch fire. There is in this case a large surface of the oxidisable material exposed in comparison with its weight.

(*c*) and (*d*). These conditions are most likely to be met with in a big pile. Inside a big pile it is not easy for the heat to escape, and although in one spot the air circulation may be too rapid and in another too slow, the probability of the circulation being just right in some place is greatly increased. The increase of danger with the height and size of the pile has been repeatedly proved. The most striking proof has been supplied by H. Fayol.*

An account of H. Fayol's excellent work at Commentry, in France, will be found in Prof. Threlfall's paper referred to above, or better still in the 1897 Report of the New South Wales Royal Commission.

Fayol built a pile of freshly mined Commentry slack coal, 40 metres long and varying in height from 6 metres to nothing. The pile was 1 metre wide at the top. The temperatures were taken daily at eleven different points in the pile; the atmospheric temperature was also recorded. Figure 1 shows:—A section of the pile with the points of observation marked, the curves plotted from the daily temperature readings, for 90 days, at six of the eleven points (the curves at the alternate points are left out to

*"Etudes sur l'altération et la combustion spontanée de la houille exposée à l'air"—Bull. Soc. Industrie Minérale, Second Series, Vol. 8, 3rd part. 1879.

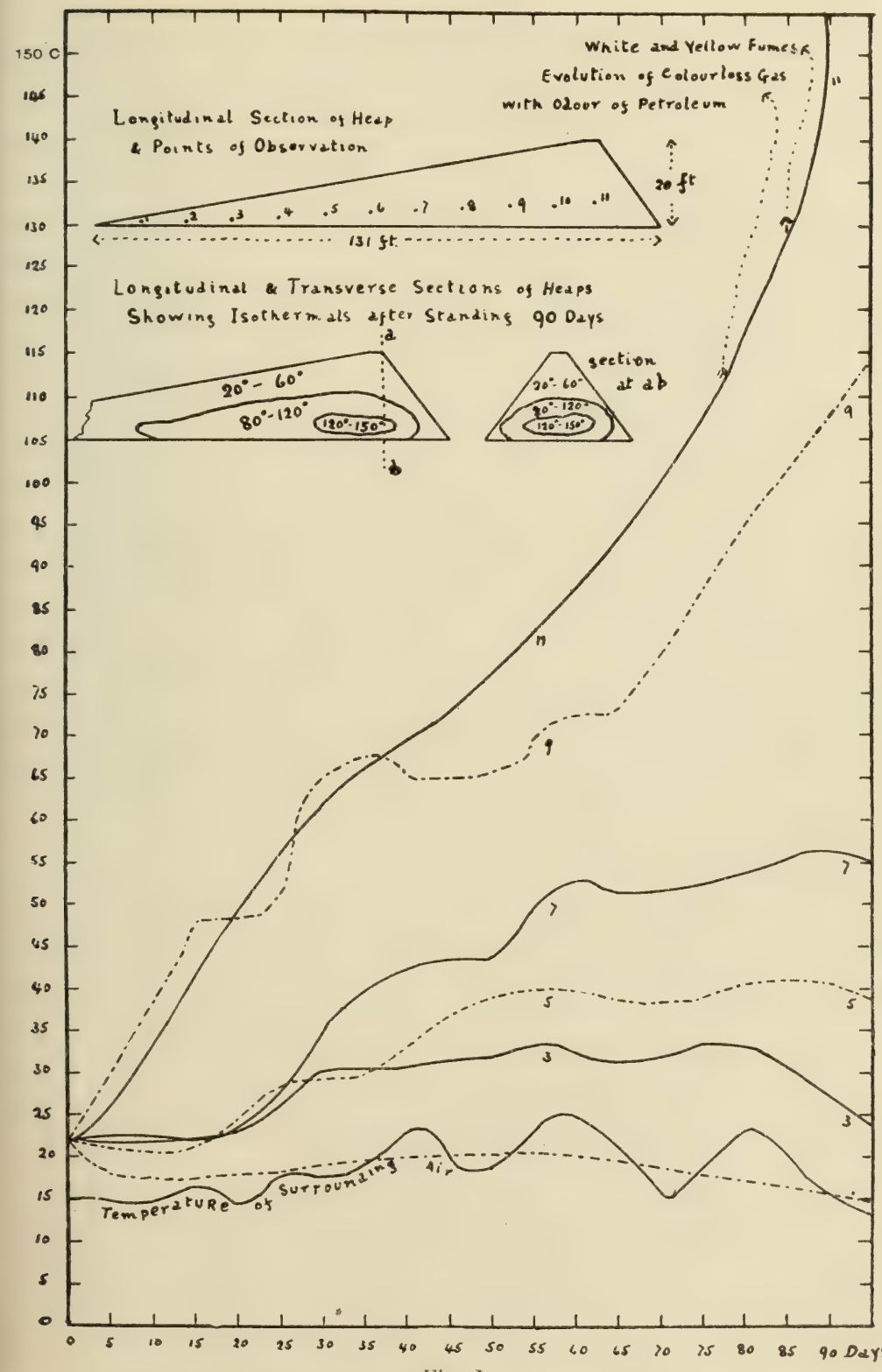

White and Yellow Fumes &
Evolution of Colourless Gas
with Odour of Petroleum
Longitudinal Section of Heap
& Points of Observation
20 ft
131 ft
Longitudinal & Transverse Sections of Heaps
Showing Isotherms after Standing 90 Days
20°- 60°
80°-120°
120°-150°
section
at ab
Temperature of Surrounding Air
150 C
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 Days

Fig. 1.

avoid confusion), the curve of the atmospheric temperature over the same period and longitudinal and cross sections of the pile at the end of 90 days with isothermal curves plotted.

The curves show that rise of temperature increases with the height of the heap and that the highest temperature occurs directly under the highest part of the heap and near the ground. In the thinnest part of the heap the coal rapidly cools from its original temperature and afterwards approximates to atmospheric temperature. Towards a height of 3 or 4 metres the temperature rises for a while and then falls again without ever passing 60° or 70° C. Where the heap is 4 metres high or over, the temperature continues to rise and ultimately the pile fires.

Fayol says:—"From whatever part of the mine it comes, whatever may be its ash content, or the nature of the ash, coal piled up in the air heats in approximately the same manner and appears in its heating to follow laws which are approximately constant. Atmospheric influences—cold or heat, drought or damp—have not been sufficiently marked to be sensible."

With Commentry slack coal no spontaneous combustion has occurred with heaps of less than 6½ feet high; but where the height exceeds 13 feet, spontaneous combustion nearly always occurs. This point, that there is a danger height for any coal, above which it is not safe to build a pile of that coal, has been repeatedly confirmed.

The New South Wales Commission have shown this same point, of increase of danger with increase of size of pile, in a quite different way. They have collected statistics of 2,149 shipments of coal, 13 of which fired or heated. Figure 2 is a curve which shows the percentage of casualties plotted against the size of the cargoes. It is quite clear from this curve that with the coal and under the conditions that these ships were loaded, the danger of heating or firing increases very rapidly when the cargo exceeds 3,000 tons.

(*e*). The danger of an initial high temperature was first established by the New South Wales Commission. Their attention being directed to the epidemic of casualties during the hot summer of 1895–1896, they were able to clearly show from their data that spontaneous fires in cargoes were associated with high maximum temperatures.

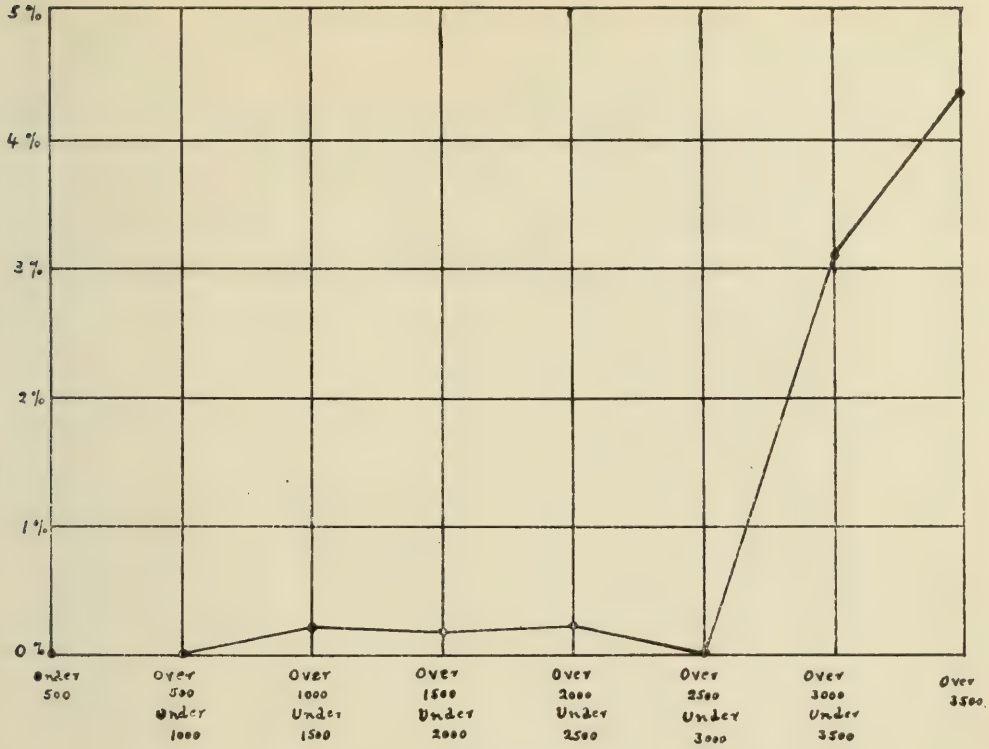


Fig. II.

Prof. Threlfall has prepared, from data presented to the British Royal Commission of 1876, by E. Cooper Rundell, the curves shown in Figure 3. The full curve shows the casualties from fire or heating for all ports of the United Kingdom, and for each month of the year, expressed as percentages of shipments of 500 tons of coal and upwards on voyages across the equator and through the Suez Canal. The figures from which the curve is plotted cover a period of 3 years and are for 4,898 shipments with 102 casualties. The dotted curve shows the mean temperature throughout the year.

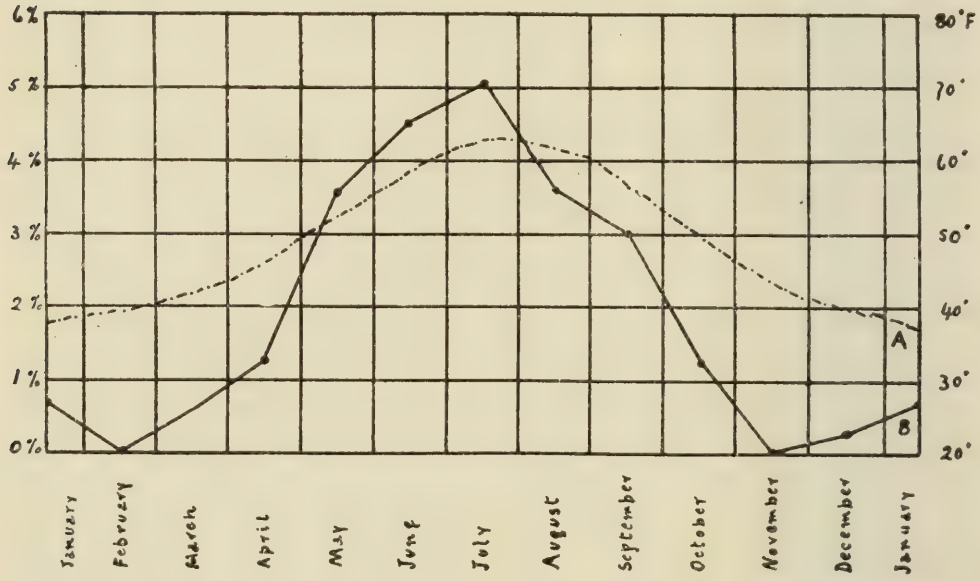
The intimate relation between the percentage of casualties and the temperature at the time of loading is beyond doubt.

It is not so easy to prove the same fact with regard to piles of coal on land. A coal pile is usually built gradually and with no record of dates or temperatures. The writer's attention was called to a coal pile which had heated rather rapidly, but which, having been built (in Canada) towards the end of September or the beginning of October, might have been supposed to have been cool to start with. Enquiries, however, had elicited the fact that the coal was observed to be warm when unloaded from the steamer

(estimated at 90° F.) although this had not been reported at the time.

One experiment by H. Fayol may be cited in this connection. He showed that by heating the coal to a high initial temperature, which was yet well below its ignition point, it was quite easy to produce spontaneous combustion even in small piles of coal. This is perhaps the most conclusive experiment that has yet been n ade as to the influence of air on the spontaneous combustion of coal. It will be referred to again later.

FIG 3



Fayol made a conical heap of coal, containing from 70 to 100 cubic feet of coal, on the ground, surrounded with a ditch which could be filled with water. A cover was put over the coal, large enough to surround the heap and fitting into the ditch, in such a way that the heap could be hermetically sealed from the external air. In one experiment the coal was heated to about 100°C. to start with. The cover was left in position, but some air holes with which it was provided were opened and shut and the temperature variations observed. When the holes were open the temperature rose, when they were closed it fell. By leaving the holes open for two days spontaneous combustion resulted, the fire was put out by closing the holes and allowing the temperature to fall to 60°C.

Very little is known of the actual chemical compounds to be found in coal, although a great deal of work has been done on the decomposition products of coal when heated. Coal has been treated with acids, alkalies, ether, alcohol, pyridine and other solvents, and the extracts examined; but the results achieved have not been very great as yet. It is certain, however, that many coals must contain unsaturated hydrocarbons and aldehydes, substances that are readily oxidised, the oxygen being added on to the molecule and not resulting in the formation or spliting off of carbon dioxide or water. Unsaturated compounds are detected by their power of absorbing bromine, as in Prof. Fischer's test described above. Aldehydes when oxidised produce acids; organic acids have been shown to be produced by the weathering of coal.

Although a great deal of work has been done on the weathering of coal, the results are very difficult to summarise, classify or discuss. Coals of all ages and qualities have been used and the weathering has proceeded under such variable and often uncertain conditions that very little can be deduced.

The chemical changes taking place in coal when oxygen is absorbed are easier to follow when proceeding more rapidly, that is, at higher temperatures. Dr. Richters of Waldenburg (Dingler's Poly. Journal Vol. 190, p. 398, Dec. 1868. Translations of several of Richters' papers are given in the Report of the New South Wales Commission) heated 2 grams of a coking coal to 190°C. for 10 hours in a current of dry, carbon dioxide free air, and collected and weighed any water or carbon dioxide produced. He found that the coal gained 4·21% in weight. The analysis of the coal before and after heating is shown in Table V.

TABLE V.

Coal dried in Desiccator.		Heated Coal.	104·21 Parts by weight of the Heated Coal, containing, consequently
	%	%	parts
Carbon	86·82	82·19	85·65
Hydrogen	4·26	3·38	3·52
Oxygen (and Nitrogen)	6·40	11.96	12·47
Ash	2·52	2·47	2·57
Total	100·00	100·00	104·21

The coal accordingly lost by heating 0·74% of hydrogen and 1·17% of carbon, but gained 6·07% oxygen. The water produced however, corresponded to 0·66% hydrogen, and the carbon

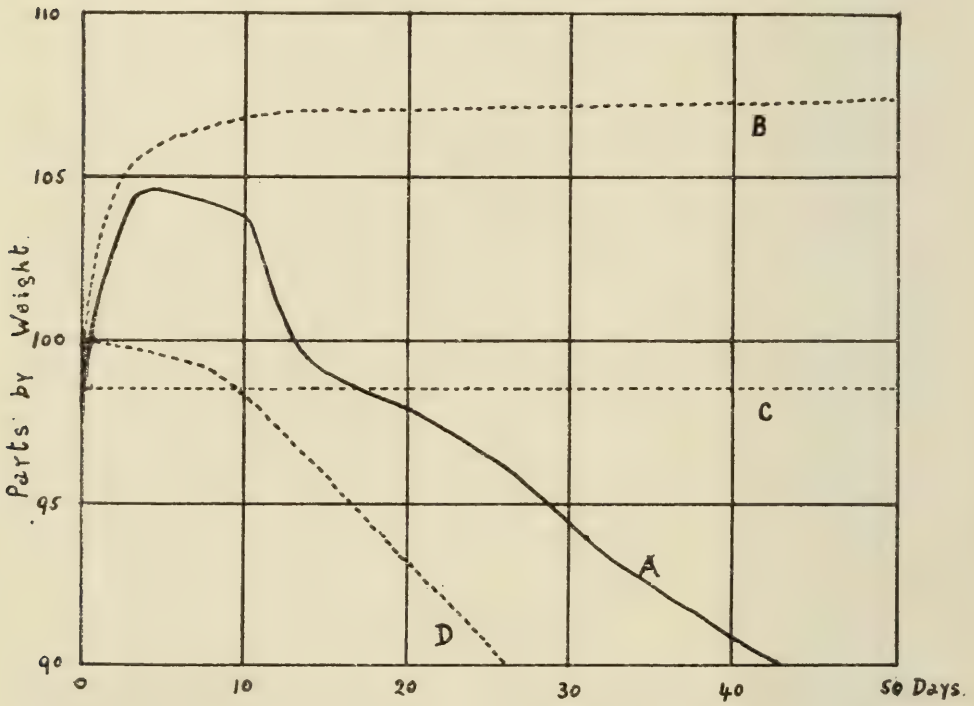
dioxide to 1·25 % carbon. The result of the experiment is therefore to show that by heating the coal in air there is complete oxidation of the hydrogen and carbon which it loses.

Dr. Richters also showed that coal would absorb carbon dioxide as well as oxygen, and that its behaviour towards oxygen was materially changed by the absorption of carbon dioxide.

H. Fayol has done similar work on the oxidation of heated coal. He continued the heating for a longer period and analysed the curve of variation of weight into its separate components. Some of his results are shown in Fig. 4.

COMMENTRY COAL IN POWDER EXPOSED TO AIR AT 200° C.

COMPONENTS OF THE CURVE OF VARIATION OF WEIGHT PLOTTED AGAINST THE EXPOSURE IN DAYS.



A is curve of variation of weight. C is curve of loss of hygrometric water.
B " " " oxygen obsorbed. D " " " loss by slow combustion.

Fig. IV.

He finds that when coal is first heated in the air to 200°C. it rapidly loses its hygroscopic water, it also absorbs oxygen with an increase of weight, rapidly at first but more slowly after a while. The coal also loses weight owing to slow combustion with the evolution of carbon dioxide and water; this is very slow at first but after about five days becomes quite rapid. The net result of these different changes is shown by the full curve, the coal first rapidly loses

weight (to the extent of its water contents) and then gains weight fairly rapidly for two or three days, it then loses weight very slowly for about seven days after which the loss of weight becomes quite rapid.

All these reactions which take place at high temperatures, in all probability also take place at ordinary temperatures, although much more slowly.

No figures showing the actual relation between the oxygen absorbed and the heat evolved seem to be available for any coal.

The oxidation of coal, as illustrated above by the work of Richters, Fayol, and Haldane and Meachem, might seem to be amply sufficient to explain the phenomena of weathering and spontaneous combustion. In spite of this, whether justified or not, there is a widespread opinion that some extra cause must be found to explain the firing of coal. Some writers appear to think that this extra cause must in itself be sufficient to heat the coal to its ignition point. This is a most improbable theory; it is far more likely that it is only necessary for the coal to be heated up to some temperature where it is still well below its ignition point but where the oxidation of the coal becomes sufficiently rapid to ultimately heat the coal up to the ignition point.

Several different ways in which coal may receive an initial heating up will now be considered.

(1). *Occlusion.* It is found that the metal palladium can absorb at ordinary temperature and pressure nearly 900 times its own volume of hydrogen. This gas does not appear to form an actual chemical compound with the palladium, but rather to be dissolved in it or possibly condensed on its surface. It is said to be occluded. When a gas becomes occluded, heat is often given out.

Charcoal can occlude large quantities of many gases. The quantity of gas absorbed increases with the pressure and is approximately proportional to it. The quantity of heat given out during the occlusion nearly approaches that set free on dissolving the gas or by its passing into a liquid condition. Cocoanut charcoal for example will absorb nearly 100 volumes of carbon dioxide at ordinary temperature and pressure; about 150 calories of heat being generated for every gram of gas absorbed.

Freshly prepared charcoal, that has been cooled in absence of air, is very liable to spontaneous ignition if exposed in large piles, this being due to the heat generated by the occlusion of the oxygen and nitrogen of the air. The actual oxidation of the

carbon is probably negligibly small until a high temperature is reached. Here, therefore, is a case where the carbon is actually heated up to its ignition point by the heat of occlusion of gases.

Coal contains a high percentage of carbon, but that is probably all in the combined state. Coal certainly does not occlude gases to anything like the extent to which any of the common forms of charcoal do.

A large number of analyses have been made of gases extracted from coal, but the experiments are hardly conclusive.

When coal is first exposed during the working of a mine, hydrocarbons are always evolved, sometimes to a very great extent; this evolution often going on for a considerable time and with a consequent reduction of the calorific value of the coal. There is no proof, however, that these gases were not mechanically enclosed under great pressure in the pores of the coal, whence they escape when the pressure is reduced. When the coal is exposed to the air, besides loosing hydrocarbons, it absorbs oxygen and nitrogen, the proportion of the former being greater than in air. This absorption may be merely a diffusion of the air into the pores of the coal together with an oxidation of the coal by means of the extra oxygen. If this coal is now placed in a vessel and the gases pumped out, oxgyen, nitrogen, hydrocarbons, etc., are obtained.

The crucial method of distinguishing between gas mechanically enclosed in the pores and occluded gas is that gas mechanically enclosed cannot occupy a greater volume, under the pressure at which it was enclosed, than that of the pores it occupies; occluded gases can occupy a greater volume, for example, palladium as mentioned above occludes many hundred times its own volume of hydrogen.

We cannot test the way the hydrocarbons referred to above are held in the coal, as we have no means of knowing the pressure to which they have been subjected.

A few examples of gases extracted from coal, at ordinary temperatures, are given in Table VI. These figures show that the total volume of oxygen and nitrogen, known to be extracted from the coal, is so small that it leaves the question, as to whether the gases were occluded or mechanically enclosed, uncertain. The difficulty of separating the gas out of the coal from the air in the containing vessel, makes it impossible to even determine the volume of the former, unless the vessel is filled with water or mercury before beginning the extraction.

TABLE VI.

EXPERIMENTER	BEDSON (1)		TROWBRIDGE (2)	PARR AND BAKER (3)					
Coal	A	A	B	C	C	D	D	E	E
Age of Coal	Freshly Hewn	Several months	?	Fresh Drill'gs	Face sam. 2 years	Fresh Drill'gs	Face sam. 2 years	Fresh Drill'gs	Face sam. 2 years
Weight of coal tested ..... grams	?	?	296	261	209	220	205	231	108
PART I.—LAST PORTION OF AIR IN EXHAUSTION OF VESSEL.									
Time coal stood in vessel after closing and before exhausting, days			?	7	9	14	2	7	1
C.C. of gas per 100 gram coal	—	—	7·4	54·2	46·2	87·4	16·4	85·5	35·7
Composition of Gas—									
Methane ..... %	Air of vessel was displaced by mercury before commencing the evacuation		16·1	22·53	—	21·79	—	23·17	—
Carbon dioxide ..... %			3·0	3·92	4·15	3·86	7·80	12·09	—
Oxygen ..... %			22·5	5·30	4·46	1·04	15·50	1·11	22·20
Nitrogen ..... %			58·4	68·25	91·39	73·31	76·70	63·63	77·80
C.C. of Oxygen + Nitrogen per 100 grams Coal			6·0	39·9	44·3	65·0	15·1	55·4	35·7
Deficiency of Oxygen as % of O+N compared with 21·0% in Air			— 6·8	+13·8	+16·3	+19·6	+4·2	+19·3	—1·2

PART II.—GAS REMOVED BY VACUUM.

Time coal stood in exhausted vessel for gases to be evolved, days	5	two fractions. 17	two fractions. 30	16	13	8	12	10	13	10
C.C. of gas per 100 grams of Coal	18	14·5	16·2	21·3	10·31	7·12	22·18	1·08	11·26	1·02
Composition of Gas—										
Methane ....%	44·60	3·58	4·52	53·4	59·59	—	86·37	—	19·26	—
Carbon dioxide ....%	1·65	1·18	0·64	7·0	17·85	80·50	7·58	—	32·09	54·60
Carbon monoxide ....%	—	—	—	0·7	—	—	—	—	—	—
Oxygen....%	8·99	23·80	20·91	3·2	4·83	1·30	0·61	—	7·32	9·90
Nitrogen....%	44·76	71·44	73·93	35·7	17·73	18·20	5·44	—	41·33	35·50
C.C. of Oxygen + Nitrogen per 100 grams Coal	9·7	13·8	15·4	8·3	2·33	1·39	1·34	—	5·58	0·46
Deficiency of Oxygen as % of O+N compared with 21·0% in Air....	+4·3	—4·0	—1·0	+12·8	—0·4	+14·3	+10·9	—	+6·0	—0·8

(1) "The gases enclosed in Coal and Coal Dust," by P.P. Bedson, Trans. Inst. M. E., 1902, Vol. XXIV, p. 27.
(2) "The gases enclosed in Coal and Certain Coal Dusts," by F. G. Trowbridge, J.S.C.I., 1906, Vol. XXV, p. 1129.
(3) "The Occluded Gases in Coal," by S. W. Parr and P. Barker, Bulletin 32, University of Illinois Engineering Experiment Station.

The large quantity of methane in fresh coal and the small amount left in coal that has been exposed to the air for some time is clearly shown in the table.

Bedson, and, working under his direction, Trowbridge frequently find the proportion of oxygen to nitrogen in the gas extracted from coal to be greater than in air; this would appear to be strong evidence for Bedson's claim that oxygen and possibly nitrogen, but proportionally more oxygen, were actually occluded by the coal.

Most experimenters, in all but a few of their experiments, find the proportion of oxygen in the gases extracted to be less than in air. As oxygen is known to be comparatively readily taken into combination by the coal, this deficiency does not necessarily disprove Bedson's statement, rather the claim is confirmed by the fact that an excess of oxygen is occasionally found. If oxygen is occluded, and to an extent compared with nitrogen relatively greater than in its occurrence in air, the experiments just cited indicate that in the majority of cases the occluded oxygen combines with the coal so rapidly that there is a deficiency of oxgyen in the gas which can be pumped out again.

The nitrogen is always in excess over the oxygen if the coal is heated before the gases are pumped out, oxidation being much more rapid at higher temperatures.

The conclusion arrived at, from the above discussion of evidence, is that the quantity of air occluded by coal is so small that the actual heat of occlusion is unimportant; but a secondary action must be considered in which the occluded oxygen is probably no longer negligible.

(2) *Oxidation Accelerated by Occlusion.* When two or more gases are occluded in the same substance, they are brought into such intimate contact with each other that they may combine with notable rapidity, although if mixed in the gaseous state combination would be inappreciable. Platinum black, gas and pipe lighters are well known examples of this type of reaction. The platinum black exposed to the air occludes oxygen, when brought into an atmosphere of coal gas or alcohol vapour these latter are also occluded, coming into very intimate contact with the oxygen they are oxidised with such rapidity that heat is generated faster

than it can be dissipated and the temperature rises to the ignition point.

Charcoal that has been heated to remove occluded gases and allowed to cool in an atmosphere of hydrogen sulphide, catches fire when placed in an atmosphere of oxygen. The oxygen combines with the previously occluded hydrogen sulphide, although if the gases be mixed under ordinary conditions no appreciable action results.

Freshly mined coal may be compared with the charcoal described above. The coal is saturated with hydrocarbons instead of with hydrogen sulphide, and exposed to the air instead of to oxygen; it is quite natural to expect that in this case also an accelerated oxidation will take place which, once begun, may easily ultimately result in the firing of the pile. Even if the coal has lost all its hydrocarbons, the occluded oxygen will be brought into such intimate contact with the readily oxidisable constituents of the coal that the same result will be reached.

Coal occludes gases to so small an extent that the action described above is not likely to heat it up to its ignition point; but only to provide the initial heating for which we have been looking. For reasons already given, open combustion will only result in a large pile.

(3) *Oxidation of Pyrites.* That the spontaneous firing of coal is due to the heat generated by the weathering of the pyrites it contained, was one of the first theories advanced, and it is still widely held. Experts such as Lewes and Threlfall now vigorously combat the idea that the pyrites do more than slightly assist.

The arguments brought forward by the two sides are somewhat as follows:—Nearly all coal contains pyrites.

Pyrites is known to be oxidised by the air in the presence of moisture, heat being thereby generated. The reaction may be written as follows: $2\,FeS_2 + 2\,H_2O + 7\,O_2 = 2\,FeSO_4 + 2\,H_2SO_4$ although it is probable that the reaction proceeds partially or altogether to the formation of ferric sulphate or basic sulphates. The pyrites may also decompose in such a way as to liberate sulphur.

The above reaction requires water, and wet coal is commonly supposed to be much more liable to fire than dry coal.

Coal mine waters often contain notable quantities of sulphuric acid, thus proving the weathering of the pyrites.

Coal heaps that have been exposed to the weather often have visible lumps of basic ferric sulphate, and ventilation holes in such piles are said to sometimes become choked up with the free sulphur deposited in them.

On the contrary, there does not appear to be any connection between the amount of pyrites in a coal and its tendency to fire.

Laboratory experiments on the oxidation of coal show that coal takes up oxygen as well or better when dry than wet, which is the reverse of what would be the case if the pyrites was being oxidised, and that the amount of oxygen taken up is often greater than could theoretically be taken up by the complete oxidation of all the pyrites present.

Fires are frequently known to have originated in dry coal.

The heat of oxidation of pyrites is only small, weight for weight coal will evolve about four or five times as much heat by its complete oxidation. A more conclusive statement would be that a given weight of oxygen evolved more heat by combining with the readily oxidisable constituents of coal than by combining with the pyrites. This is probably true, but the writer is unacquainted with any work which has been done that would prove it.

Pyrites, by weathering, could hardly heat itself up to ignition point, much less the coal surrounding it; in fact, heaps of pyrites free from carbonaceous material are never known to fire spontaneously.

Prof. Lewes said that as pyrites can liberate sulphur, the ignition point of which is lower than that of coal, he at first thought that pyrites might cause danger by thus lowering the ignition point. He found, however, that sulphur oxidises faster than it could be liberated, even at temperatures as low as 60°C., so that this danger cannot exist.

In considering these arguments we must remember that there are different varieties of pyrites, that known as marcasite weathering much more rapidly than the ordinary variety. The fine flakes of pyrites, sometimes scattered throughout the coal, are probably marcasite and certainly weather faster than the larger lumps.

A single match may ignite a pile of shavings, a single flake of marcasite might cause a warm spot that may result in a coal pile firing. This might explain the fact that the tendency for a coal pile to fire is not proportional to the percentage of sulphur or pyrites present.

We are not at present looking for something to heat the coal to its ignition point, but only to give it a little initial heating. If sulphur is liberated from pyrites and oxidises (both actions being accompanied by an evolution of heat) at low temperatures, it might easily act as a starter, although the sulphur did not remain as such to lower the ignition point.

The crucial question seems to be, does the coal or the pyrites generate heat the faster by its normal oxidation at low temperatures ? The evidence seems to be strongly in favour of the answer: the coal. This would thus rule pyrites out of account as the usual cause of fires. It is of course always conceivable that under certain circumstances this might be reversed and the pyrites blamed; but this probably seldom or never occurs.

On one point all parties are agreed. When flakes of pyrites weather they expand and fracture the coal, and thus expose more and fresh surfaces for oxidation and indirectly increase the danger of heating. As a general rule, however this breaking must be slight compared with that caused by handling, although it will certainly assist in the deterioration of the coal.

4. *The Action of Water.* This is an even more knotty point than the preceding one. On the one hand we have scientific evidence to prove that coal oxidises less when wet than when dry, and on the other an almost universal and deep-rooted opinion, amongst men of practical experience of the storage of coal, that wet coal is dangerous.

The scientific experiments of Richters and others must carry conviction as far as they go; at the same time it appears dangerous to assume, without the very fullest proof, that the opinions of the practical men are simply the relics of an old superstition, bolstered by forgetting facts that appear to contradict and only remembering confirmatory facts.

A British Royal Commission on coal investigated this problem in 1876. The Commissioners said:—Most of the witnesses who have come before us have strongly condemned the shipment

or carriage of coal in a wet condition, and their experience in this respect is, to a certain extent, supported by the scientific evidence .....It would appear that the wetting of certain kinds of coal, more especially those containing pyrites, is active in promoting spontaneous combustion; but the statements of some of the witnesses lead to the impression that moisture has been credited with cases of combustion beyond the sphere of its operation; while from other passages of the evidence, it appears to us that the influence of the water, existing to a greater or less extent, in all coal before it has been brought to the surface, has not been sufficiently recognised."

The two scientific experts of the Commission, Dr. Percy and Professor Abel, said, "Spontaneous ignition of coal, when due to the oxidation of the porous and readily oxidisable carbonaceous substances occurring in coal, does not appear to be favoured by the presence of water in the coal or by its access to a cargo; on the contrary, these portions by becoming wet, would have their pores more or less filled with water, and their power of absorbing oxygen would be proportionally diminished, hence the presence of water must be antagonistic to the action of the latter in many instances, though, when iron pyrites is present, it may promote or accelerate spontaneous heating, as already pointed out."

In spite of the quotations above the report of the Royal Commission of 1876 seems to have been taken as condemning the shipment of all wet coal. The King's Regulations and Admiralty Instructions, Article 523, paragraph 25, read:—"Coal should not be taken on board wet, as moisture sometimes causes a rapid and dangerous generation of heat and gas.....Coal should always be kept as dry as possible." This paragraph has, however, since been rescinded.

The New South Wales Royal Commissioners stated in their Report of 1897 that:—"It must still be regarded as an open question, however, whether the heating of Newcastle coal is in any way dependent on the amount of moisture which it contains. On the one hand, we have the very definite experimental result of Fayol that moisture has no influence whatever on the liability to spontaneous combustion of the coals of Commentry, and, on the other, we see that the disintegrating action of oxidising pyrites may have an indirect effect."

It may here be stated that the effect of water in disintegrating pyritic coal is always conceded, although many persons hold that except with highly pyritic coal it is not very important.

The N. S. W. Commission after making the first report, carried out a further investigation to determine the effect of water upon stored coal. Two large wooden bins were built and both filled with slack coal under as nearly identical conditions as possible except that in filling the one the coal was kept dry and in the other was throughly wet during loading by water from a hose. The wet coal was found to be 10°C. cooler to start with, and, although it heated slightly at first, after 46 days the mean temperature in this bin showed a steady decline that continued until the 139th day, when the temperature readings were discontinued. The dry coal, on the contrary, grew steadily, although at first slowly, hotter, and after 63 days the bin had to be flooded and the heated coal dug out in order to avoid a fire.

The 1900 Report says that to the question the Commission set out to solve, therefore, they return "a direct and unconditional answer. Coal is less liable to spontaneous combustion when it is loaded wet than when it is loaded dry."

The Report disposes of the findings of the 1876 Commission as follows:—"The British Commission received 26 answers to the effect that wet coal was the more dangerous. But an analysis of the evidence discloses that 25 of these answers were based on 'general impression' or hearsay evidence only, while the 26th was not tested by cross examination. The opinions referred to were held, not by scientific men, but by those engaged in the coal trade .....All such views, it seems to us, must now be definitely abandoned."

A case in confirmation of these views is that of the sailing ship *Strathdon* which sailed with coal from Newcastle, N.S.W., on June 16th, 1900, arriving at San Francisco on August 25th. It rained very hard whilst some of the coal was above ground awaiting shipment, and the coal became so thoroughly wet that water ran out of the trucks during loading. The wet coal was charged into holds 2 and 3, holds 1 and 4 being filled with perfectly dry coal. The holds were 23.6 feet deep, temperature tubes 22 feet long were inserted into the body of the cargo through the hatchways and the temperatures were regularly taken and recorded in the log-

book. The air temperatures were 62° F. at start, 92° at the equator, and 72° at discharge. In the dry holds the temperatures were 74° F. at start, rising to 94° and 92°, and falling to 94° and 84° at discharge; in the wet coal the corresponding temperatures were 62° F., maximum 77° and falling to 74° and 75° at discharge. The maximum temperature difference was 22° F. and the average 13.8° F., the wet coal being the cooler.

On the other hand, V. B. Lewes cites the case of a ship carrying a cargo of coal where the main hatch was filled in dry weather and the after hatch whilst it was raining. After a few days the temperature was about 10° F. higher in wet coal than in the dry, spontaneous ignition being the ultimate result.

Prof. Lewes' opinion is that at first external wetting retards the absorption of oxygen, but that the presence of moisture afterwards accelerates the action of the already absorbed oxygen upon the hydrocarbons; he draws a sharp distinction between wet coal and damp coal, it being the latter that he considers dangerous.

Enough has now been said to show the complexity of the subject. Before proceeding further with its discussion it will be well to define what is meant by dry coal. Coal as taken from the mine, or that has been exposed to rain, contains water that it gives up when exposed to dry air; when it no longer loses weight it is said to be "air dry." If air dry coal is ground up and subjected in a thin layer to a temperature of 105° C. for one hour, it loses a further quantity of water and is now said to be "dry." This definition of dry coal is quite empirical, it would be very rash to assume that it was free from water, it certainly contains the elements of water and can readily be made to give up actual water. Dry coal, in questions of handling and storage, usually means air dry coal.

It is probable that water was first blamed for the spontaneous ignition of coal, on account of a false analogy with the heat produced by the fermentation of dry hay. Further, it is sometimes noticed that the top of a coal pile feels warm the day after a shower of rain. The obvious explanation of this is not that the water causes the coal to heat, but is, as suggested by the New South Wales Commission, that the pile was already hot inside. The water trickling down came to the hot coal, was turned to steam, and rose to the surface where its warmth was felt.

It is often pointed out that many chemical reactions, that take place readily or even violently under ordinary conditions, will not take place at all if the reacting bodies are exceedingly dry. This is no argument, however, in favour of the danger of storing wet coal. The amount of water needed for such reactions is so very small that certainly all air dry coals, and probably all dry coals, contain far more than is necessary for any chemical action in which water is merely an accelerator and is not one of the reacting bodies, as in the weathering of pyrites.

Richters has carried out experiments upon the rates of oxidation of damp and of air dry coal. He showed that not only does the air dry coal absorb oxygen faster than the damp coal, but by putting some calcium chloride into the vicinity of the former, so that it becomes still dryer, its rate of oxygen absorption is further increased.

Coal immersed in water, being practically protected from the oxygen of the air, is subject to little or no deterioration. It was therefore natural to expect that wet coal would also be considerably protected from oxidation, but there was the possibility that damp coal might be worse than either wet or dry coal. Richters' results, if generally true, clearly show that this is not the case, dry coal being most readily oxidised. Experiments are being carried out to test this point by the University of Illinois (see Bulletin 17) and the University of Missouri (see Bulletin 1). The results of their work, which is not yet completed, can so far hardly be said to confirm or disprove Richter's conclusions.

The writer's own opinion is that water always retards the oxidation of coal, except in its effect on pyrites, but that indirectly it may have a marked influence for good or for bad on the condition of stored coal. Some of these ways in which the coal is influenced are well known, others are here put forward as tentative suggestions.

Firstly, Fayol has stated that by building up a coal pile in thin layers, allowing sufficient time for the first rapid oxidation of each layer of coal to take place whilst the heat generated can be easily dissipated into the air, before covering with another layer, a coal pile can be safely built to any height. Generally coal will be partially oxidised before storing and the danger thus be reduced; but if coal is taken wet from the mine, or is wet soon after mining,

and is stored still wet, this preliminary oxidation is largely prevented. The coal then drys out and the first most rapid and energetic oxidation takes place in the pile where the heat accumulates and danger results.

Secondly, a warm coal thoroughly wet by rain or by deliberate spraying will be cooled by the water itself and also by its subsequent evaporation. The coal is thus, as in the New South Wales bin experiment, cooler than it would have been dry and the initial temperature being lowered the danger is reduced.

Thirdly, it has already been stated that in coal cargoes fires almost always begin in the cone under the hatchway where the small broken coal accumulates and where there is consequently the largest proportion of surface exposed for oxidation. When dry coal is dumped there is the same tendency for the small coal to settle into a compact mass towards the bottom where, unless it is too compact to allow the air to circulate, will be similarly the greatest danger of heating. When coal is wet the dust and small particles cling together and adhere to the larger lumps, so that a pile built of wet coal is likely to be more homogeneous from top to bottom. This difference in the mechanical distribution of the coal may easily make a great difference to its tendency to fire; it is possible that in some cases the danger is thereby increased and in other cases decreased.

Fourthly, after a pile has been built, if it is exposed to heavy rain the dust and fine coal are washed down and form a dense layer one or two feet below the surface. This also must have a great effect on the air circulation through the pile and consequently on its tendency to fire. If the circulation was previously too rapid for serious heating, the danger will be increased; if too slow, it will be made still slower and the danger of ignition will be decreased.

If these views are correct, water is a preservative for all coal except the pyritic, but that wetting the coal before or after storing may do much good or may do much harm. It is probable that when our knowledge of the air circulation and rate of oxidation in coal piles is increased, water will be a good servant; at present it is a dangerous ally.

5. *Heat of Oxidation of Bituminous Shales.*—Bituminous shales from the coal seams often fire as easily, possibly more easily, than

the coal itself. It is said that in cases of trouble with Cape Breton coal in Montreal, a piece of shale is usually found in the centre of the heated portion; but this may be merely a coincidence. The problem yet to be solved is—does the pure coal or the shale oxidise and evolve heat the faster at ordinary temperatures.

6. *External Heat.*—The initial heating may be the result of boilers, steam pipes or flues near to the coal, or of cotton waste, which if soaked in some oils oxidises readily, and which if allowed thus to get into a coal pile might easily, cause a hot spot. Again, where wood comes in contact with coal it is often noticed that the fires begin in close proximity to the wood. This may be due to heat evolved by the rotting of the wood or to some modification of the air currents caused by the wood.

7. *Heat of the Sun.*—It has been shown above that the hotter the coal when stored the greater is the danger, coal being black absorbs the sun's rays readily and may easily reach a temperature considerably above the shade temperature at the time. If coal when on a car before dumping, or on the surface of a pile, becomes heated by the sun and if the warm portion is then buried under more coal, a fire may easily result. This appears to be a case where a judicious spraying with water would prove a safeguard.

The New South Wales Commission made some experiments and found that on seven successive days the maximum temperature three or four inches below the surface of some coal exposed to the sun varied from 25·6°F. to 36·8°F. higher than the maximum shade temperature on the same days.

It seems to be doubtful whether most coal piles are prevented from firing by an excess or a deficiency of air. Fires in ships begin under the hatchways where, it is true, the most air might be expected, but they begin in the cone of fine coal where the circulation can only be slight. The remedy would therefore seem to be to increase the ventilation; but, on the contrary this is found in practice to be the worst thing to do. Fires in coal piles generally begin near the bottom away from the air, and yet again ventilation is said to be dangerous. Thorough ventilation would certainly prevent fires in either case.

V. B. Lewes says that for ventilation to do any good, cool air would have to flow continuously and freely through every portion of the coal. Steam coal he says will absorb twice its own

volume of oxygen in ten days under favourable conditions. A ton of such coal occupies 42 or 43 cubic feet, of which 12 cubic feet is air space, a ton will therefore absorb 60 cubic feet of oxygen in ten days, which represents 300 cubic feet of air or 25 times the volume of the air contained in it; that is to say, if these figures are correct, there would have to be a complete change of air every ten hours.

It is difficult to understand how air can circulate through a large pile of slack coal, it looks to be almost impossible. The air does not appear to come in through the sides of the pile as fires occur indiscriminately near the sides or in the centre and their position is not apparently affected by the direction of the wind. One possible explanation is that inequalities of temperatures in the pile cause convection currents, air descending from the top in some places and ascending in others. Two or three somewhat casual inspections of a large pile, ventilated with a large number of vertical holes passing from top to bottom, failed to anywhere discover a down draught, warm air appeared to rise from all the holes and in winter when the pile was covered with snow melted passages through to the surface.

The absorption of the oxygen of the air in a pile by the coal, leaving behind the lighter constituent of the air, nitrogen, will cause fresh oxygen to pass in by diffusion, changes of barometric pressure will also effect a slight air circulation through a pile. When the pressure is low not only will the air in the interstices expand, but air dissolved in water in the coal and occluded gases will also be given off, the amount of gases dissolved or occluded being proportional to the pressure. When the pressure increases there will be a flow of air back into the coal to fill up interstices, dissolve in the water and to be occluded. The amount of such air currents up and down will be greatest at the surface and decrease steadily downwards; the circulation best suited to cause fires might therefore be expected to be some fraction of the height of the pile; as a matter of fact, fires usually occur about two-thirds of the way down. We have so far assumed that the ground on which the pile rests is impervious, but if it is a light sandy soil the surging of the air up and down with barometric changes will take place not only through the pile but also through some of the soil below. The amount of air passing through the coal from this

cause will be thus increased and, together with the air circulated by other causes, may be too great to cause a fire even at the every bottom of the pile. This idea is in accordance with the fact that coal piles give more trouble on wet clayey soil than on dry sandy soil; but it has been suggested to the writer that the rising and falling of surface moisture in the soil are more likely than barometric changes to cause a cooling air circulation through the coal. Those who believe in the theory that wet coal is dangerous say that coal fires on a clayey soil because it remains damp owing to the poor drainage.

Whatever the explanation, it at anyrate appears certain that it is well to store coal on well drained ground; a thick bed of cinders is often used as a foundation.

It is just possible that some coals contain enough occluded oxygen when stored to allow a considerable amount of oxidation to take place without any access of fresh air. Parr and Hamilton* find that samples of coal deteriorate in even the most carefully sealed containers. They examined some coal that had been unopened in an airtight jar for three years, a lot of the pyrites was found to be oxidised to ferric sulphate, this was leached out and determined and it was found that the oxidation which had been accomplished corresponded to 1·99 grams or 1·39 litres of oxygen, equivalent to 7 litres of air! The coal was buckwheat size, filling a pint jar three-quarter's full. This result is hard to understand when compared for example with Parr's own figures showing the small amount of oxygen occluded in coal; but it is possible that the iron pyrites was oxidised at the expense of oxygen compounds in the coal.

Fayol's experiment described elsewhere (page 157) does not, as might be supposed, prove that coal cannot heat with occluded oxygen alone. When he cut off the air supply the coal certainly cooled, but it was then over 100° C. and any occluded oxygen would have combined with the coal below that temperature. Coal may heat with occluded oxygen, but as it gets hot, fresh air must be supplied or it will cool again; such hot coal will, however, tend to draw in the fresh air required by means of convection currents.

* "The Weathering of Coal," Bulletin 17 of the University of Illinois Engineering Experiment Station.

If iron pyrites and the oxygen compounds of coal can react, it suggests that possibly also fresh coal and weathered coal may react and thus make a dangerous mixture. There is no clear evidence on this point; Fayol says that coal spread in successive layers of not more than 3 ft. and with a lapse of time after each layer before putting down the next, forms a safe pile. Other writers say that coal once heated and cooled never heats again, and yet, the foreman of a coal yard in Montreal states that mixtures of old, heated and cooled, coal with fresh coal are very dangerous; and a case has been cited where in building a coal pile banking was stopped for a month and then continued, fires afterwards breaking out all along the line of contact of the old and the new coal. These fires might be explained as being due to mixing, or possibly, the surface of the old coal was strongly heated by the sun when the new coal was put on the top.

Coal is banked near the mines in Cape Breton in piles of twenty or even thirty feet high without a sign of heating, the same coal stored in Montreal heats in less than three months in piles of only half the height. The difference is probably due to the coal in Cape Breton being in comparatively large lumps, coming straight from the mine saturated with hydrocarbons, and being stored in winter and therefore cold; the coal in Montreal on the contrary being more broken up and almost like slack, being saturated with air rather than with hydrocarbons and being stored in summer and therefore often hot.

Remedies for trouble with coal piles are easy to suggest, but are often difficult and expensive to carry out. Storage under water has been successfully tried by the British Admiralty and others, and the former has also shown that coal briquettes can be stored without serious loss even in hot climates. Continuous storage under water could not easily be adopted in Canada, as in winter when the coal was wanted the water would be frozen; but it would probably be practicable to so store in a cement tank from which the water was drained in the autumn when it was reasonably cold.

Very few coals will heat if stored in piles of less than ten feet high, or a thicker pile can be safely made if it is very thoroughly ventilated. Fayol's suggestion of building up a pile in thin layers might be tried, or Threlfall's recommendation of spraying.

The question is largely one of dollars and cents. A cement tank involves a large capital outlay; but with proper handling machinery the coal need hardly cost as much each year for storing as it would in an ordinary stock pile. A ventilated pile requires no capital beyond the handling arrangements also required for the unventilated pile; but the annual outlay in providing vent holes is considerable. Coal stored under water suffers no appreciable deterioration chemically or physically. Stored in air but kept fairly cool it may lose 5% in value, authorities differ very much on this point; coal which heats although it does not actually fire, may lose up to 20 or 25% of its value, and an actual fire may involve great expense to extinguish it, in addition to the damage to the coal. In any particular case the outlays involved and the economies effected must be considered in deciding between the different methods of storing. It is, however, greatly to be deplored that the coal resources of the country should be needlessly wasted by spontaneous combustion.

A coal pile should always be regularly tested until the probable period of incubation is past or until the temperature having first risen begins to steadily fall again. The simplest method of testing is by means of iron rods run down through the pile at frequent intervals. These should be pulled out once or twice a week, their temperature being felt along their length, and then put back in a fresh place. If dangerous heat develops in a ventilated pile it is best treated by making extra ventilation holes; if this does not succeed, or in an unventilated pile, it is well to dig away the hot coal and spread out to cool. Digging out is also the best remedy in case of fire. It is well to begin by digging all round the heated spot to isolate it, as otherwise it may spread back into the rest of the pile as air gets to it.

Water is not found successful in extinguishing fires. In the first place the coal above the fire cokes and thus armours the fire over and the water cannot readily penetrate through. Cases have been known where in digging out ships' cargoes, hollow spaces were found near the bottom containing only ashes. A fire had begun, armoured itself over and burned out without its presence having been suspected. Secondly, water may cause the fire to spread, as the steam generated passing through the pile heats up fresh coal which also soon fires. Fayol showed that coal, even in small piles, soon fired if first heated to 100°C.

Since this paper was written an account of further work of the University of Illinois Engineering Experiment Station has been published—Bulletin No. 38, "The Weathering of Coal," by S. W. Parr and W. F. Wheeler. The conclusions from their experimental work are as follows: "Coal of the type found in Illinois and neighbouring States is not affected seriously during storage when only the changes in weight and losses in heating power are considered. The changes in weight may be either gains or losses of probably never over two per cent. in a period of one year. The heating value decreases most rapidly during the first week after mining and continues to decrease more and more slowly for an indefinite time. In the coals that have been tested, one per cent. is about the average loss for the first week and three to three and one-half per cent. would cover the losses for a year, although in some instances the loss was found to be as high as five per cent. in a year."

"The losses due to disintegration of the coal and to spontaneous ignition seem to be of far greater importance than any changes in weight and heating value, although they cannot be expressed in figures for comparison. The storage of coal of a size larger than is to be used would overcome part of this objection to storage, as the coal could be crushed to the most advantageous size just before firing. The larger sizes of coal are also much less liable to take fire spontaneously. Storage under water will prevent disintegration of the coal to a very large extent, and it will absolutely prevent any fire losses. Aside from these advantages in favour of storing coal under water, there seems to be very little to be said in favour of any particular method of storing coal."

The subject of spontaneous combustion is very big and this paper comes far short of covering even the work already done; but it will at any rate serve to indicate the incompleteness of our present information.

In conclusion, the writer wishes to thank Dr. Porter for his assistance in obtaining references and papers and to thank him and others for their valuable information, criticisms and suggestions.

THE HOSMER MINES, LIMITED, (BRITISH COLUMBIA.)*

By HARRY H. YUILL, Montreal.

One of the most striking and encouraging features of Canadian mining to-day is the manner in which the coal deposits of the west are being developed and operated. Many of the older mines, that were handicapped to a very considerable extent by the method of development, have carried out, and are still carrying out, schemes of re-development, while in some localities a change of mining method has been found necessary.

The realization of the importance of an efficient surface plant has resulted in the installation of up-to-date machinery, and the erection of the magnificent steel tipples such as those at Michel, Lethbridge and Hosmer.

Within the past twelve months a well-developed and thoroughly equipped mine has entered the market for the sale of coal and coke. This mine is at Hosmer, B.C., a town in the Elk River Valley, 8 miles north of Fernie and on the Crow's Nest Branch of the C.P.R.

The equipment there is adequate to the requirements of maintaining an output of about 4000 tons a day.

The holdings of the Hosmer Mines, Limited consist of six sections of coal lands and two sections of surface area, upon which the town of Hosmer and most of the surface plant connected with the mine, are located.

The two sections of surface area bordering the railroad were purchased from the Crow's Nest Coal Company.

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* Awarded Commans-Frecheville-Marriott Prize, (Paired with F. E. Lathe.)

Elk River at Hosmer, B.C.

The occurrence of coal in the Elk River Valley was mentioned in a Report to the Geological Survey of Canada in 1880–82, and later by Dr. Selwyn of the Geological Survey, who visited this district in 1891.

In 1900, Mr. J. McEvoy made a detailed geological examination and map of the district for the Geological Survey.

The coal bearing rocks are those of the Kootenay formation, at the base of the Cretaceous. The Rocky Mountain Ranges are a series of fault blocks of Laramie age, dipping to the west. The folding and faulting of the region are on a large scale, and in some places the displacement to the east reaches a maximum of seven miles. The process of erosion has removed the younger and softer rocks to such an extent that remnants are found only on the rear slope of a fault block and next to the succeeding fault block, where they have been more or less protected. Hence the coal measures that occur in the Kootenay formation lie in long narrow strips between the mountain ranges and parallel to them. The three major basins in the Rocky Mountains are, the Elk River Basin, the Crow's Nest Basin, and the Cascade Basin.

In the Southern Elk River Basin, situated west of the summit of the Crow's Nest Pass, the coal-bearing rocks have reached a maximum thickness of 4700 feet, and contain 22 workable seams of high grade bituminous coal. This basin has an estimated area of 230 square miles and 216 ft. of coal with about 100 ft. of this workable coal. This gives an estimated workable coal content of 22,600,000,000 tons. The present collieries are situated at Coal Creek, Michel, Morrisey and Hosmer. Fernie is the chief shipping centre.

The Northern Elk River basin has an area of about 140 square miles, and an estimated workable coal content of 14,000,000,000 tons. The basis of this estimation is explained as follows in the Government report, 1909:—

> "In one place, Aldridge Creek, for example, it is estimated "at 16 square miles, with a total thickness of 163 ft. of coal. "If 100 ft. be extracted, then, on the assumption that the "whole area of 140 miles is of equal value, the total coal may "be estimated at, say, 100,000,000 tons per square mile, or a "total of 14,000,000,000 tons."

It must be emphasised that these figures are very general; nevertheless they indicate the immensity of the coal content of these basins that may be worked, in so far as the thickness of the individual seams is the only factor. But the topography of the country, and the existence of faults of considerable dimensions present certain difficulties to be reckoned with before a proportion of this coal may be profitably mined.

When the vast mineral resources of the Kootenays were discovered and smelters built to treat the ores, a considerable demand for coal was created and emphasised the need of establishing railway communication with the coal areas.

In the year 1888, an Act was passed by the Legislature of British Columbia, incorporating the Crow's Nest and Kootenay Lake Railway Company, and empowering the Company to construct a line of railway, from some point at or near the junction of Summit Creek with Michel Creek, to a point on the Lower Kootenay River at or near its junction with Goat River. The name of this Company was afterwards changed to the B.C. Southern Railway Company.

The Railway Aid Act of 1890 provided that the Lieutenant-Governor in Council might grant to the B.C. Southern Railway Company, 20,000 acres of land for each one mile of said railway completed. These lands were to be taken in alternate blocks on each side of the line of railway, and each block was to have a frontage on the line of railway of 20 miles, so that the land granted by the Government on one side of the line of railway should be opposite to a like 20 miles of land retained by the Government on the other side of the line of railway. Section 16 of this Act reads as follows:—

> "Wherever, along the line of said railway, the full "quantity of 20,000 acres per mile in alternate blocks cannot "be had, the deficiency shall be made up of a belt of land "five miles in width along the East side of Elk River, extend-"ing between a point five miles below Morrisey Creek, and a "point 28 miles above Michel Creek, and from a belt 2½ miles "in width, on each side of Coal Creek, extending to the "summit, and from a belt three miles in width on each side "of Michel Creek, and on each side of East and West branches "of said Creek to the summit."

1. View looking up Incline, Hosmer, B.C.
2. View looking down Incline.
3. Hosmer in Winter.

In 1897 the B. C. Southern Railway Company was given permission by the Dominion Government to lease its works, or any part thereof, to the Canadian Pacific Railway Company, for any period agreed upon by the two companies, and sanctioned by the Governor in Council.

The following proviso was inserted:—

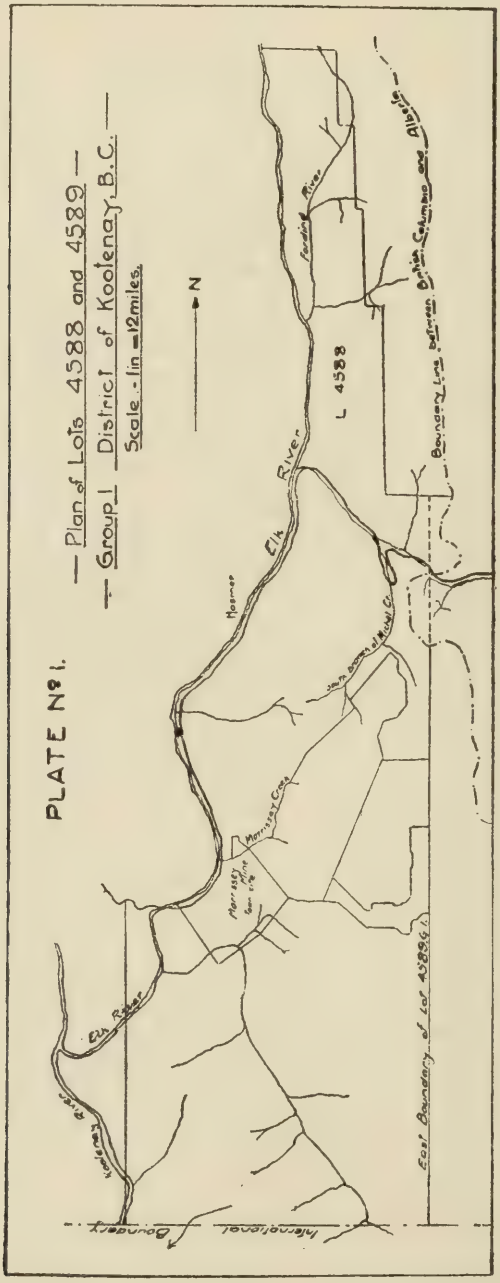
"(i.) That if the Company, or any other Company, "with whom it shall have any arrangement on the subject, "shall, by constructing the said Railway or any part of it, "as stipulated for in this agreement, become entitled to, and "shall get any lands as subsidy from the Government of "British Columbia which, in the opinion of the Director of "the Geological Survey of Canada (expressed in writing), "and coal-bearing lands, then the Company will cause to be "conveyed to the Crown in the interest of Canada, a portion "thereof to the extent of fifty thousand acres to be selected "by the Government in such fair and equitable manner as "may be determined by the Governor in Council, and to be "thereafter held or disposed of, or otherwise dealt with by "the Government; as it may think fit, on such conditions, if "any, as may be represented by the Governor in Council, "for the purpose of securing a suitable and sufficient supply "of coal to the public, at reasonable prices, not exceeding "two dollars per ton of two thousand pounds, free on board "cars, at the Mines."

The agreement made with the Canadian Pacific Railway, in the same year, was to the effect that the Canadian Pacific Railway would construct the Crow's Nest line, as per specifications, descending Michel Creek on the Western Slope of the Mountains, crossing the Northern part of the coal lands, and following Elk River downward, nearly along the line of the Western boundary of the Cretaceous area, for a distance of 25 miles. They were also to construct branches to the coal mines at Coal Creek, Morrisey and Michel.

The completion of the railway in 1898 entitled the British Columbia Southern Railway Company to the above mentioned subsidy of lands. The full quantity of 20,000 acres per mile, in alternate blocks could not be had, therefore the land grant was modified, as provided for in Section 16 of the Railroad Aid Act,

1890. This grant was made in 1899 and comprised lots 4588 and 4589, Group 1, Kootenay District. (See Plate 1.)

The British Columbia Southern entered into an agreement with the C.P.R., and the Crow's Nest Coal Company, that if,



by the construction of the Crow's Nest line, or any part of it, they should become entitled to, and receive any lands as subsidy from the Government of British Columbia, the following 'disposition should be made of said lands:

1. In the case of lands, which are not coal-bearing lands, they shall be disposed of to the public, according to Provincial regulations, and at prices not exceeding those prescribed from time to time by the Governor in Council.

2. In the case of lands which in the opinion of the Director of the Geological Survey of Canada (expressed in writing) are *coal-bearing* lands.

(a) 50,000 acres in fee simple to the Government of Canada.

NOTE—These Government lands were selected in two blocks of 45,000 acres and 5,000 acres respectively. The latter lie wholly within the belts of land described in Section 16.

(b) 6 Sections of 640 acres each in fee simple to the Canadian Pacific Railway.

NOTE—The C.P.R. made an agreement with the Crow's Nest Coal Company whereby they could not mine coal in these blocks for sale, or for their own use, until Dec. 19, 1908.

(c) Conveyance to the Crow's Nest Pass Coal Company in fee simple, all such lands described in Section 16 estimated at 250,000 acres, excepting the Government 5,000 acres and the C.P.R. six sections, and any part of the Government 45,000 acres which may lie in these described belts of land.

Also 10,000 acres which do not lie in the belts of land but lie in lot 4589.

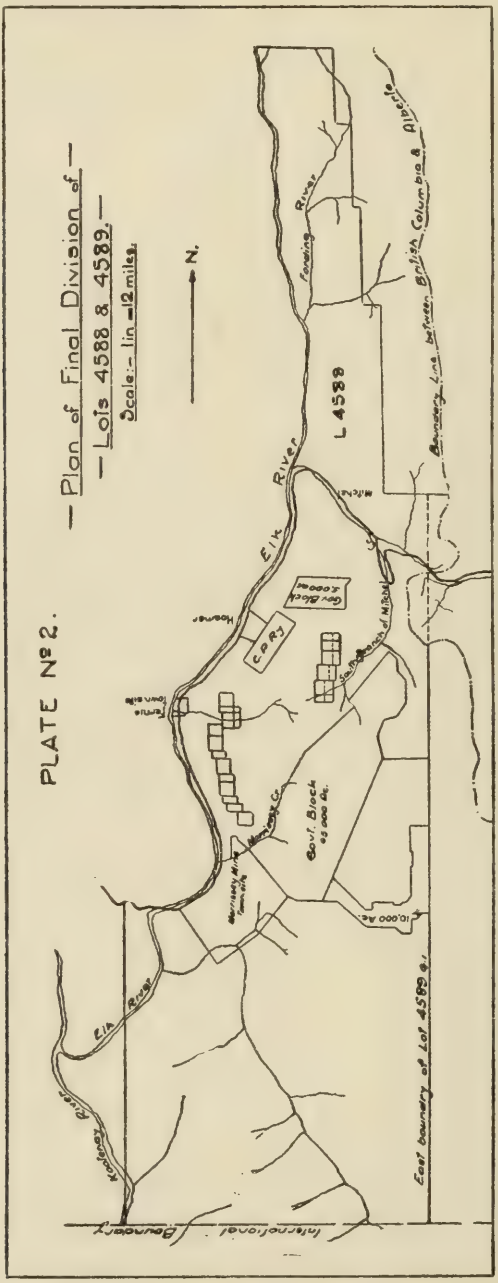
See Plate II. Plan of these various blocks of coal lands.

The Coal Company in turn, among other things, agreed to develop the coal mines, and supply all the available markets with coal at reasonable prices, and to pay taxes on the C.P.R.'s six sections should these be taxed before December 19, 1908.

The Coal Company and C.P.R. gave each other mutual rights of way.

The completion of the Crow's Nest line in 1898, had an important bearing on the mining industry of Southern British Columbia. Until that time the coal and coke supplies were derived from the Vancouver Island mines. The carriage charges therefrom were excessive, consequent on a long up-grade haul and one or more inconvenient transfers. On the other hand the coal from the Crow's Nest Pass can be delivered into the heart of the mining districts without breaking bulk, delivered in cars,

loaded at the mine, and hauled down an easy grade to points of consumption.



The following figures supplied to the British Columbia Government, by Mr. Peters, the C.P.R. District Freight Agent in Nelson, in 1898, show the difference in the selling price of the respective coals:—

RETAIL PRICES.

Freight Rate, Coal and Coke from					Coast to Nelson	5.25	per	ton
"	"	"	"	"	Crow's Nest "	2.25	"	"
Price Screened Coal at Nelson from					Coast.	10.00	"	"
"	"	"	"	"	Crow's Nest..	5.75	"	"
"	Coke	"	"	"	Coast.	11.00	"	"
"	"	"	"	"	Crow's Nest..	7.00	"	"

The coal from the Crow's Nest was also sold in the Western States and in the N.W.T.

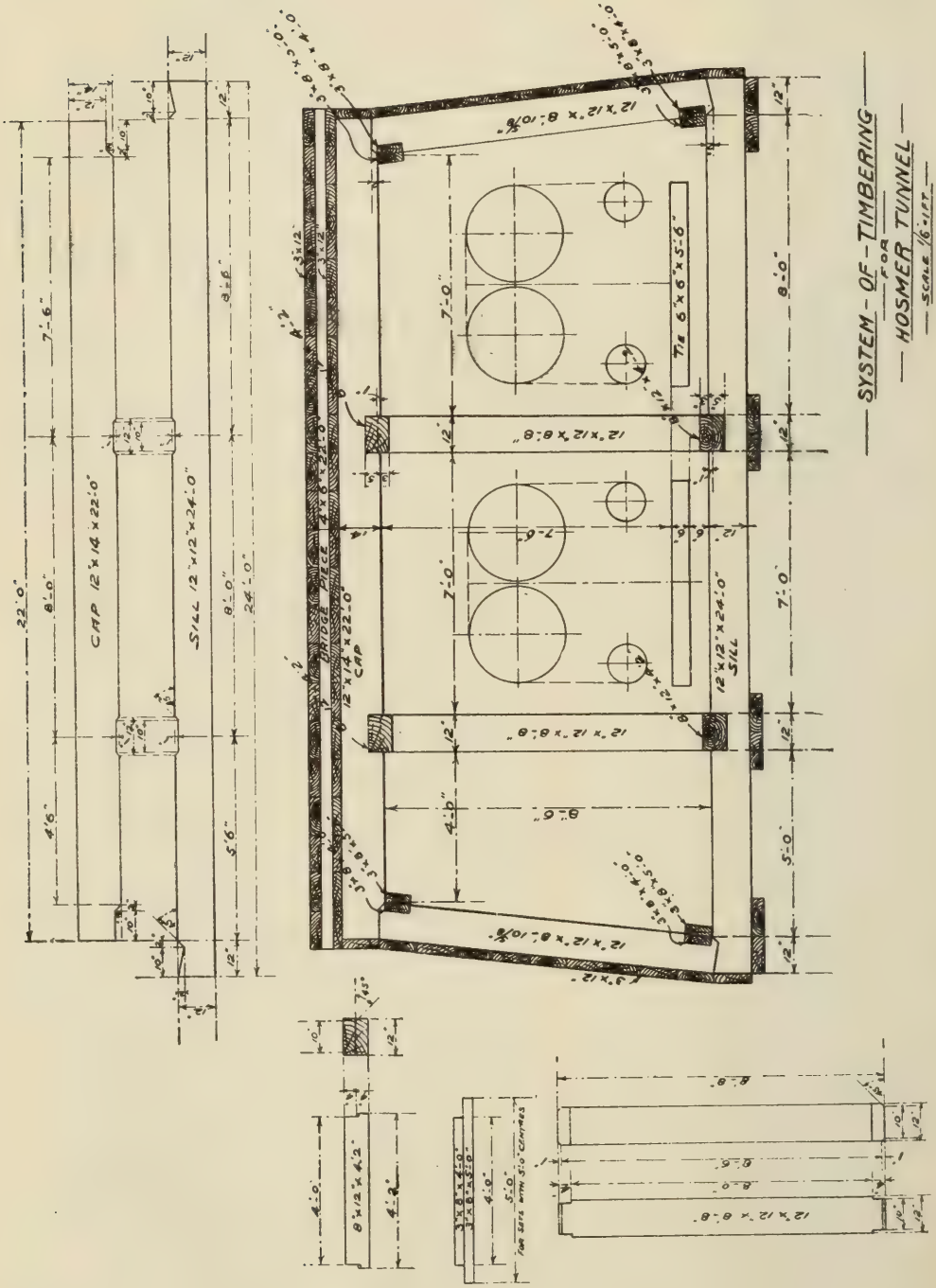
As the Canadian Pacific Railway could not mine coal for their own use, or for sale, until Dec. 19, 1908, the output from this basin to date has been derived almost exclusively from the mines of the Crow's Nest Pass Coal Company whose production has been as follows:

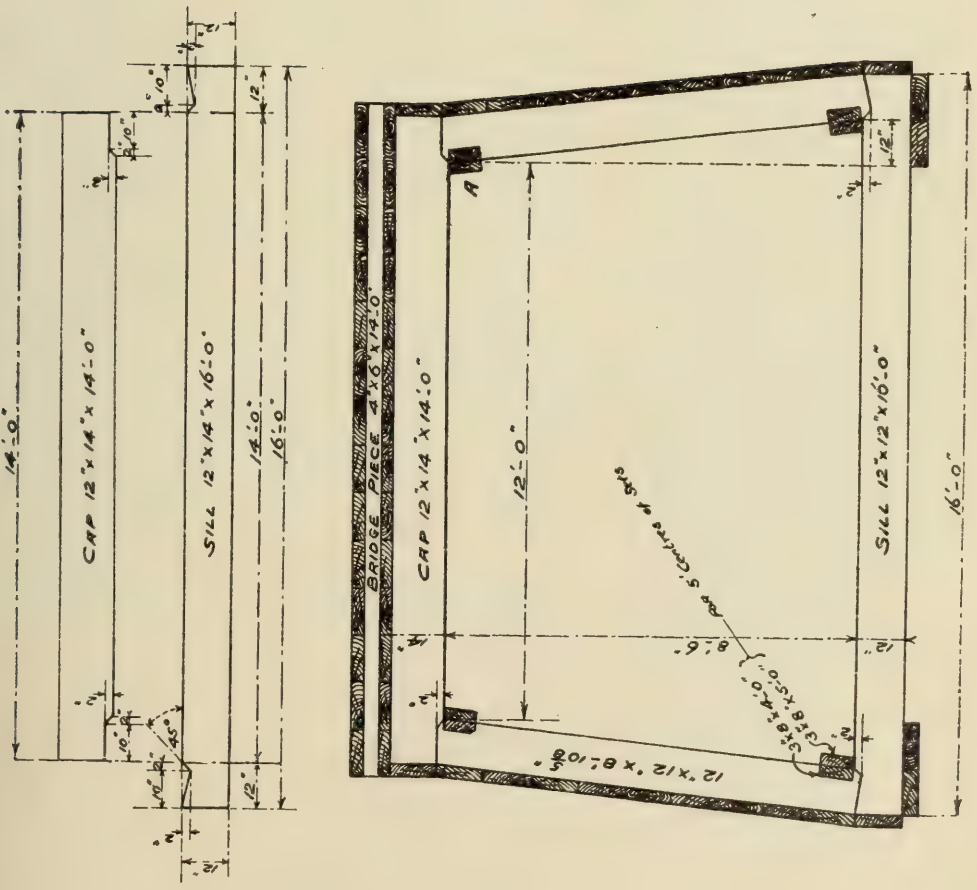
PRODUCTION.

		Coal Production	Coke Production.
	1898.	8,986 tons	361 tons
	1899.	116,200 "	29,658 "
	1900.	220,458 "	73,496 "
	1901.	425,457 "	125,085 "
	1902.	441,236 "	120,777 "
	1903.	661,118 "	167,739 "
	1904.	742,210 "	245,118 "
	1905.	831,249 "	257,702 "
	1906.	806,901 "	213,295 "
	1907.	981,939 "	231,368 "
	1908.	467,737 "	240,609 "
Hosmer Mine	1908.	2,627 "	771 "

The attitude of the coal-bearing formation in the blocks of land owned by the Hosmer Mines, Limited, is described in a general way in Mr. McEvoy's Report, as follows:—

"The upturned Western edge of the Cretaceous rocks "form a ridge or escarpment which runs parallel to the Elk "River and three to four miles distant therefrom. The


SYSTEM OF TIMBERING
FOR
HOSMER TUNNEL
SCALE ½"=1'-0"
CAP 12"x14"x22'-0"
SILL 12"x12"x24'-0"
BINDER PIECE 4"x6"x22'-0"
CAP 12"x14"x22'-0"
SILL 12"x12"x24'-0"
TIE 6"x6"x5'-6"
12"x12"x8'-10½"
12"x12"x8'-8"
12"x12"x8'-0"
22'-0"
8'-0"
7'-6"
4'-6"
5'-6"
24'-0"
7'-0"
12"
8'-6"
4'-10"
8'-0"
5'-0"


SYSTEM OF TIMBERING
FOR
HOSMER TUNNEL
SCALE 3/16=1FT.
A
3"x8"x4'-0"
3"x8"x5'-0"
4'-0"
5'-0"
FOR SETS WITH 5'-0" CENTRES
CAP 12"x14"x14'-0"
SILL 12"x14"x16'-0"
14'-0"
16'-0"
12"
BRIDGE PIECE 4"x6"x14'-0"
12'-0"
8'-6"
12"x12"x8'-10½"
3"x8"x5'-0"
3"x8"x4'-0"
45°
5' Centres of Sets

"height of the escarpment is fairly uniform, being 3500′ to "4000′ above the river. About half way up the slope the "coal measures are found outcropping, with dips of 30° to "40° eastward."

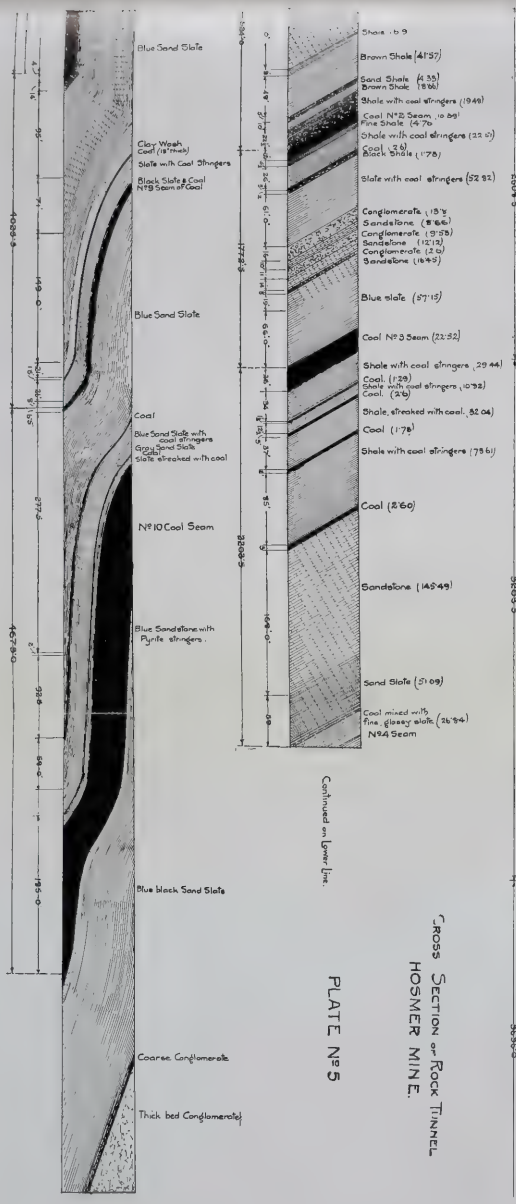
The Hosmer Mines, Limited, commenced active operations in 1906 by driving two parallel tunnels S. 48° E at right angles to the coal measures. The larger tunnel is 24′ wide by 10′ high and has three compartments, two for haulage purposes, and the third as a travelling and pipe way. (See Plate III.) The smaller tunnel is 16′ wide by 10′ high. It is of one compartment and is used as a return airway in connection with the ventilation of the mine. (See Plate IV.) These tunnels were started at a point 605′ higher than the railway track at Hosmer Station, in the Fernie shales which underlie the coal measures; hence the first seams reached are the lowest of the series. At a point about 4900′ in, the tunnels reached the hard conglomerate which overlie and protect the coal measures.

The situation of the coal measures is clearly shown in Plate V, which is a section along the main tunnel, and is also shown in a more general way in Plate VI, which is a profile section along the tunnel showing the location of the coal seams at out crop and where intersected by the tunnels. It can be seen from these sections that the geological work has been most painstakingly and systematically performed. Considerable work has been done towards correlating the section here with that at Coal Creek; but the entire section has not been successfully correlated. It may be noted here that Seam No. 9 at Hosmer corresponds with seam No. 2 at Coal Creek.

In driving the tunnel ten seams of coal were cut having a total thickness of 116′ of coal; five seams having a total thickness of 48′ are workable.

The workable seams are as follow:—

No. 2. seam.	10′	coal
No. 6 "	7′	"
No. 8 "	6′	"
No. 9 "	5′	"
No. 10 "	20′	"


Blue Sand Slate
Clay Wash, Coal (18"mud)
Slate with Coal Stringers
Black Slate & Coal
No 9 Seam of Coal
Blue Sand Slate
Coal
Blue Sand Slate with coal stringers
Grey Sand Slate
Slate streaked with coal
No 10 Coal Seam
Blue Sandstone with Pyrite stringers.
Blue black Sand Slate
Coarse Conglomerate
Thick bed Conglomerate
Shale (1'9)
Brown Shale (41'57)
Sand Shale (4'38)
Brown Shale (1'86)
Shale with coal stringers (19'49)
Coal No 2 Seam, (0'89)
Fire Shale (4'70)
Shale with coal stringers (22'0)
Coal (3'6)
Black Shale (1'78)
Slate with coal stringers (52'82)
Conglomerate (15'8)
Sandstone (5'66)
Conglomerate (9'58)
Sandstone (12'12)
Conglomerate (2'0)
Sandstone (19'92)
Blue slate (57'15)
Coal No 3 Seam (22'52)
Shale with coal stringers (29'44)
Coal. (1'29)
Shale with coal stringers (10'32)
Coal. (2'6)
Shale, streaked with coal. (32'04)
Coal (1'78)
Shale with coal stringers (73'61)
Coal (2'60)
Sandstone (148'49)
Sand Slate (51'09)
Coal mixed with fine glassy slate (26'84)
No 4 Seam
Continued on Lower Line.
Cross Section of Rock Tunnel
Hosmer Mine.
Plate No 5
Mouth of Tunnel
Slate with coal stringers (114'79)
Sandstone (170'61)
Sand Slate (32'04)
Slate with coal stringers (16'49)
Coal. Stringer of Slate (8)
Coal (13'07)
Coal with streaks of slate (24'8)
Fernie Shale 785'6"
Blue sandy slate (127'71)
Layers of hard sandstone and fine conglomerate (205'5)
Fine grained conglomerate (47'71)
Dark sandy Shale (140'74)
Shale streaked with Coal (10'48)
No 6 Coal (9'91)
Coal (0'65)
Dark sandy shale with coal streaks (29'5)
No 7 Coal
Soft brown Shale Dipping 20° to 30°
Black Shale with Nigger Heads
Blue Sand Slate Flatter Measures 10° to 15°
No 8 Seam Coal
Slate with coal stringers
Blue Sand Slate
Dark grey Sandstone
Grey Sandstone (204'7)
Coal (1'3)
Brown Shale (4'10)
Coal No 1 Seam (1'3'8")
Brown Shale (30'51)
Sandstone (96'89)
Shale (82'04)
Sandstone (95'2b)

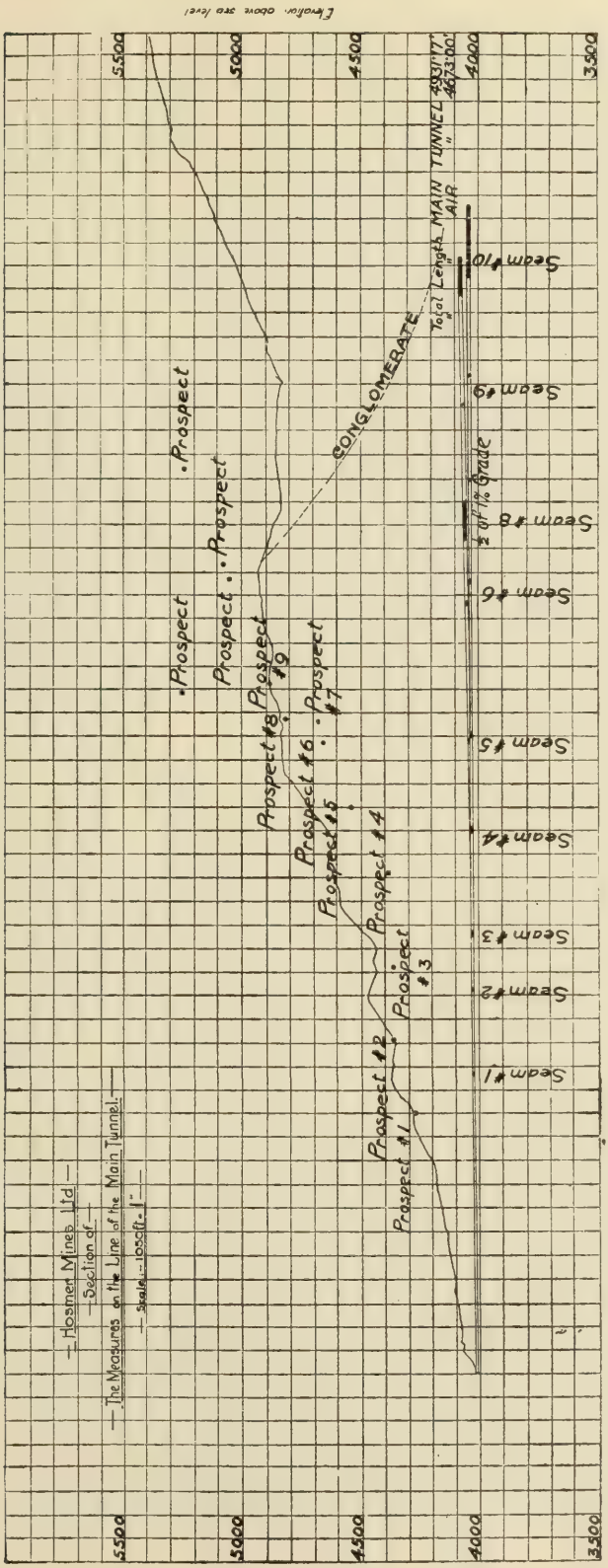

Elevation above sea level
5500
5000
4500
4000
3500
Hosmer Mines Ltd.
Section of
The Measures on the Line of the Main Tunnel.
Scale 1 inch = 100 feet
Prospect
Prospect
Prospect
Prospect #9
Prospect #8
Prospect #7
Prospect #6
Prospect #5
Prospect #4
Prospect #3
Prospect #2
Prospect #1
CONGLOMERATE
Total Length MAIN TUNNEL 4931'7"
AIR 4673'00"
Seam #10
Seam #9
Seam #8
Seam #6
Seam #5
Seam #4
Seam #3
Seam #2
Seam #1
2% of 1% Grade

PLATE N°6

No. 2, which was the first workable seam reached by the tunnels, has been developed more than the others, and has produced most of the tonnage to date. The coal in this seam is higher in ash than in any of the other workable seams. It is an excellent coal for household use.

Development, Gangways, S. 1000′, N. 800′.

No. 6 seam produces probably the best coking coal encountered, and averages about 9% ash.

Gangways, N. 600′, S. 500′.

No. 8. seam was encountered by the tunnels in a disturbed area. Both the north and south gangways, which are driven only 200′ each, passed out of this disturbed area within 100′ of the tunnels.

No. 9. seam is a clean, coking seam and produces excellent steam coal.

Gangways, N. 100′, S. 200′.

No. 10 seam is possibly the best encountered for coking and steam coal. It has an exceptionally good roof.

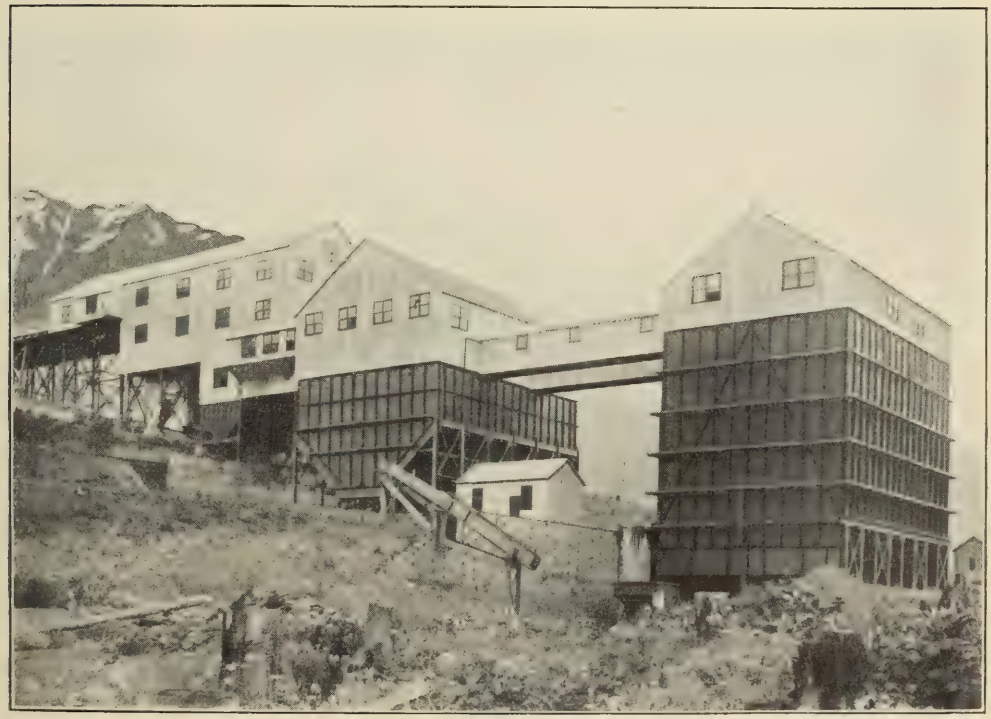
Gangways, N. 200′, S. 200′.

Seams Nos. 2 *and* 6 having been developed more than the others are, consequently, producing most of the present output of coal, which is about 500 tons of run of mine coal per working day. This output will be gradually increased until it reaches from 2000 to 3000 tons per day.

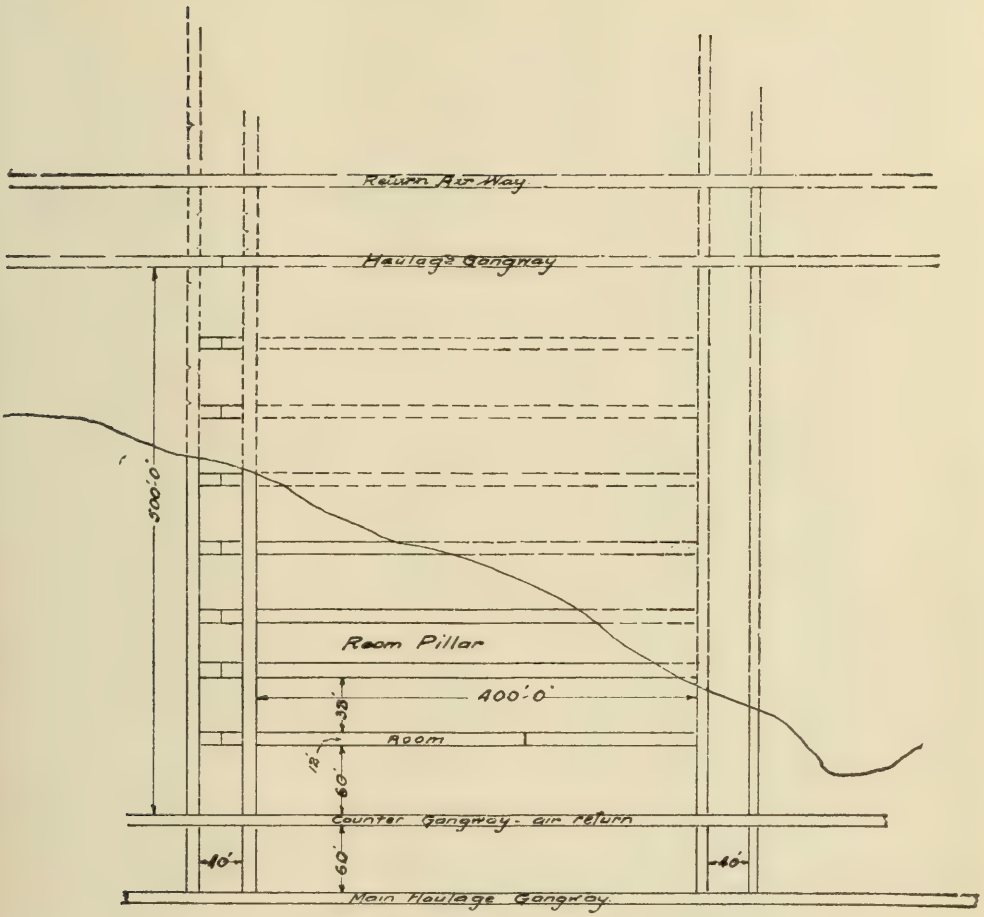
The room and pillar system is employed in mining the coal. The working face is sheared and then picked down. The mine is equipped with twelve Liskol and two Whitcombe shearing machines. No blasting powder is used, and as a certain amount of gas is encountered, safety lamps of the Wolfe type are in use. The method of attack is as follows:—

Off the main tunnels gangways are driven having a small grade to facilitate haulage and drainage. Shutes are then driven up the slope of the coal, every 400′, and the rooms which are nearly level are driven off at right angles to these entries. The coal is trammed from the working face and dumped into a chute in the entry that extends to the main haulage gangway. Here the coal is loaded into mine cars of 2 ton capacity, and hauled by compressed air locomotives to the tunnel. These cars are drawn out of the main tunnel by air locomotives in trips of 30—40.

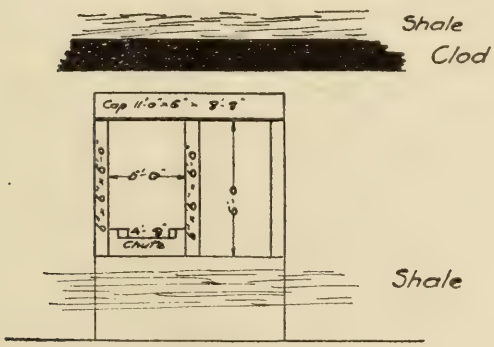
Tipple at Hosmer, B. C.—West Elevation.



Tipple at Hosmer, B. C.



Sketch of Method of Working Coal



Timbering in Entry

PLATE No. 7.

The size of rooms and pillars is shown in Sketch Plate VII. It is proposed to drive levels at intervals of 500′ vertically, thus dividing the seams into lifts of 500′.

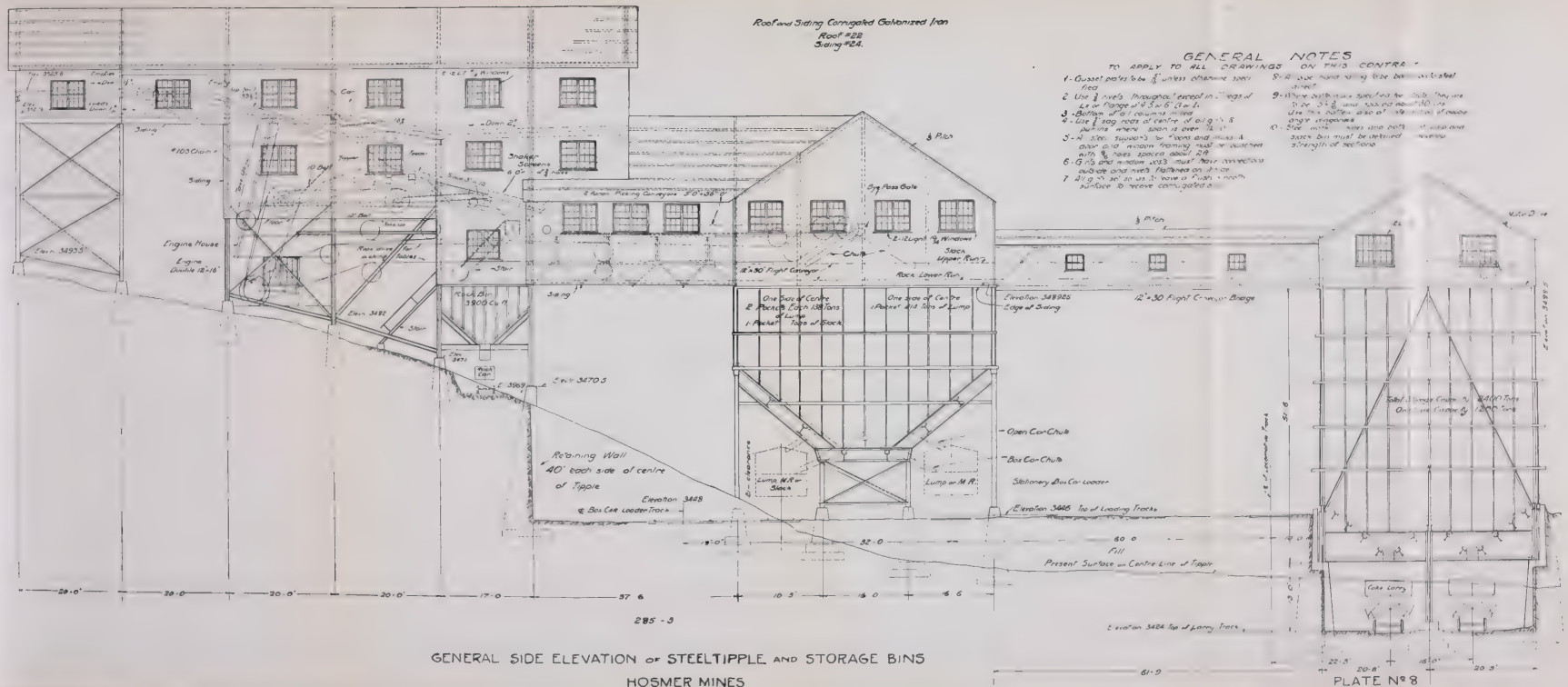
The coal is lowered in "trips" of 20 cars from the tunnel mouth (elev. 4011) to the bottom of a steam actuated double track incline (elev. 3531) 3550′ long, of which one side only is in use at present. The mine cars are then hauled across a substantial wooden trestle (see accompanying photographs) to the tipple by compressed air locomotives, and there dumped on a Phillips Cross Over Dump into a steel box from which it is fed by a reciprocating feeder to the shaking screens, size 16 ft. by 6 ft., with ¾ inch punched holes. The coal then passes on to two steel picking belts, 4 ft. 9 in. wide and 65ft. long, where boys pick the refuse from it. The lump coal discharges into storage bins of 2400 tons capacity, and the slack is conveyed to bins with 3000 tons capacity by a scrape conveyor. The return side of the slack conveyor carries rock and refuse to a rock bin of 200 tons capacity; it is then drawn out into self-dumping cars, and hauled to the refuse dump, by an air locomotive. The lump coal is loaded into the railroad cars direct, and the slack is taken by air locomotives from the slack bin in seven ton larries to the coke oven.

The coke ovens are of the beehive type and number two hundred and forty. They are 12′ in diam., 7′ high, and will provide an output of 300 tons of coke per day.

The tipple (Plate VIII) is built entirely of steel, with corrugated roofing. It is designed to operate in 2 units, each of which may be worked independently of the other. At present, only one-half is in use, but the second half will be put into commission when the output warrants it. The tipple construction was commenced in March, 1908; the steel work which was done by the Roberts and Schaefer Company of Chicago, was started in May, and completed about the middle of October.

1200 cub. yds. of concrete were used in the piers and retaining walls.

All the permanent buildings of the surface plant except the fan engine house, which is built of brick, are of reinforced concrete construction, and the tunnel entries are of concrete, as is also the connection of the smaller tunnel with the fan. A 9′ x 20′ Walker fan, speed 150 revolutions per minute, provides ventilation for


Roof and Siding Corrugated Galvanized Iron
Roof #22
Siding #24.
GENERAL NOTES
TO APPLY TO ALL DRAWINGS ON THIS CONTRACT
1 - Gusset plates to be ⅜ unless otherwise specified
2 - Use ¾ rivets throughout except in angles of Lt or Flange of 9.5 or 8. (3 or 1).
3 - Bottom of all columns milled
4 - Use ¾ stay rods at centre of angles & planking where span is over 12 ft.
5 - All stiffeners to be 4 long and mitred at corners and made to fit angle with ⅜ holes spaced about 2 ft
6 - Girts and intermediate girts must have connection outside and not fastened on flat side
7 - All angles to be so as to leave a flush smooth surface to receive corrugated sheeting
8 - All bolts unless specified to be ¾ diameter
9 - Where bolts are specified for splices they are to be ⅞ and ¾ respectively
Use the latter also at the ends of cradle angle irrespective
10 - Size of rivets, sizes and pitch of holes and stock bin must be retained to keep strength of sections
Engine House
Engine Double 12"x16"
Elevn 3493.5
Elevn 3492
Elevn 3470.5
Elevn 3469
Elevn 3487
Rock Bin 3900 Cu Ft
Retaining Wall 40' each side of centre of Tipple
Elevation 3488 to Box Car Loader Track
Shaker Screens
Stock Upper Floor
Rock Lower Floor
One Side of Centre 2 Pockets Each 138 Tons of Lump 1 Pocket 138 Tons of Stock
One side of Centre 1 Pocket 213 Tons of Lump
Elevation 3489.25 Edge of Siding
12'-30° Flight Conveyor Bridge
Open Car Chute
Box Car Chute
Stationary Box Car Loader
Elevation 3486 Top of Loading Tracks
Fill
Present Surface on Centre Line of Tipple
Elevation 3484 Top of Lorry Tracks
Take Lorry
285-9
GENERAL SIDE ELEVATION OF STEELTIPPLE AND STORAGE BINS
HOSMER MINES
PLATE Nº 8

General View of Trestle, Hosmer, B.C.

The Machine Shop and Trestle, Hosmer, B.C.

Mouth of Large Tunnel.

Phillips Cross-over Dump.

the mine. It is driven with a rope drive by a pair of 16 x 30 engines, originally the steam end of the Rand Compressor, which runs at 100 revolutions per minute. The fan is ordinarily run as an exhaust, but it can be changed to a blow fan, at short notice, and is capable of supplying 300,000 cub. ft. of free air per minute. The steam for the fan engine is supplied by 3 "Economic" boilers 80 H.P. each. The other buildings at the tunnel mouth are a concrete lamp house, a locomotive house for the compressed air locomotive, and a well equipped wash house, (with lockers) for the miners.

The main power houses and shops are at the foot of the incline.

The boiler house is a building of reinforced concrete provided with steel roof trusses covered with corrugated iron. 391 yds. of concrete were used in the construction of this building; it is 70 x 50 ft. and contains six 250 horse-power Babcock & Wilcox Water Tube boilers, equipped with chain grates and mechanical appliances for handling the coal and ashes. The building is designed to hold eight of these boilers, the other two will be installed when needed—and the floor of the building is of concrete.

The power house is of the same construction and contains:—

2 Norwalk compressors, steam 26″ x 30″, 2 stage to 100lb sq. in., each having a capacity of 1659 cu. ft., of free air per minute. The air from these compressors is used for the rock drills in tunnel, shearing machines, timber hoists in the mine, and various other purposes around the plant.

2 Norwalk compressors, steam 26″ x 30″, 3 stage, 50lb, 250lb, 900lb; each having a capacity of 840 cu. ft. free air per minute. The air from these compressors is used for charging the Porter air locomotives, of which there are five, 2–7″ x 14″ at the mine, 1–6″ x 10″ and 2–7″ x 12″ below the incline; main reservoir maximum 900 lb. Aux. reservoir running 140lb sq. in.

In the power house are two 75 K.W. General Electric A.C. generators, volts full load 2300, amperes 18.85, speed 900, which are driven by two Robb Armstrong engines 14″ x 14″ These provide power for the lighting of the town and the mine plant.

All the engines have adjustable cut-off valves; the purpose is to supply steam at 120lb sq. in., cut off at $\frac{1}{4}$ stroke and use the steam expansively.

The steam from any or all of the engines can be turned either into the atmosphere or through a 1500 horse power Hoppe's exhaust steam heater 5′8″ dia. by 9′ long, which heats the boiler feed water to 204° F. This building is 53′ x 87′–20′ wall. Six hundred and thirty yards of concrete were used in the walls and foundations. The walls are heavily reinforced, 1–2–4 mixture of concrete was used for the curtain walls, while 1–3–6– mixture was used for foundations and the other walls.

The haulage engines are in a building conveniently situated near the bottom of the incline. These engines which were made by the Vulcan Iron Works, Wilkesbarre, Penna., are a pair of first motion engines 28″ x 48″ with two 8′ drums having 4 foot faces. The clutches, brakes and reversing gear are all controlled by steam working through cataract cylinders.

The power for the shaking screens and picking belts in the tipple is derived from an Atlas Duplex Engine, 12″ x 16″. The Slack rock conveyor is driven by a 25 horse power electric motor.

The power for the Chicago concrete mixer, and the Austin gyratory crusher which breaks to $1\frac{1}{4}$″ is supplied by a $8\frac{1}{2}$ x 10 portable engine and boiler, placed on trucks.

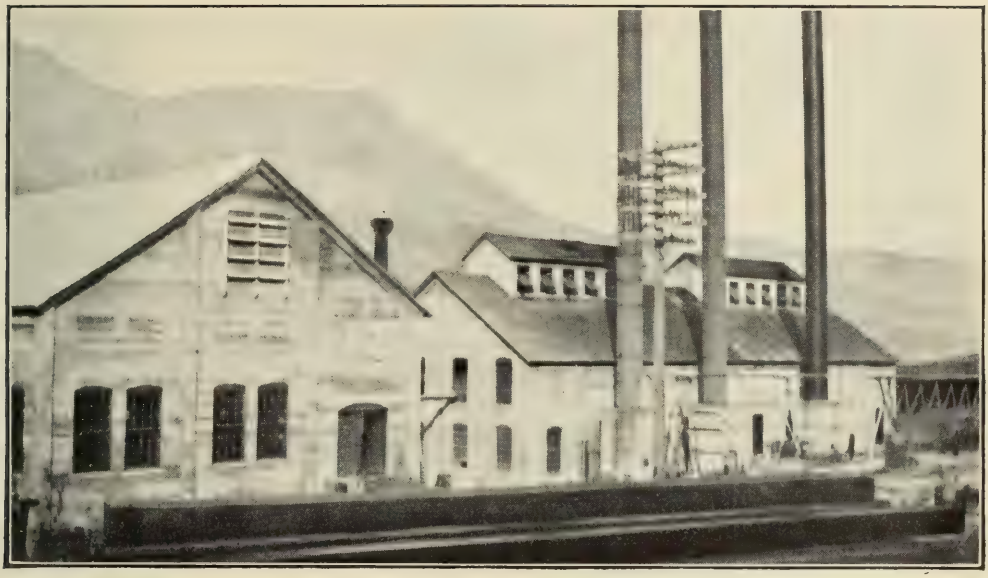
The various shops are well equipped, as follows:—

Blacksmith Shop:—1. No. 2. double punch and shear; 25″ throat belt driven; 1. David Bell Standard guide frame steam hammer, 6″ x 18″ cylinder, weight 7200 lbs.; 1 Plate bending roll; 1 36″ forge; 1 48″ forge; 1 60″ forge; and a Sturtevant-Sheldon Blower.

Machine Shop:—1 pipe cutting and threading machine; 1 Norton Pedestal grinding machine; 140″ grind stone; 1 McCabe Double Spindle Lathe 26″–48″ swing; 24′ between centres, 30′ bed; 1-16″ x 10″ screw cutting lathe, $\frac{1}{2}$″–18″ swing, 6′ centres; 1 30″ x 30″ heavy pattern planer; 1 3′ combination radial drill with worm swivelling table; 1 14″ sensitive drill, drill chuck up to $\frac{1}{2}$.″

Carpenter Shop:—1 Universal rip and crosscut saw; 1 band saw; 1 perfection planer and jointer; 1 single spindle vertical boring machine; 1 24″ swing wood lathe with countershaft.

With this equipment all the repairing necessary can be done on the premises, while the shops are also capable of making mine-cars, etc.



Power House and Boiler House, Hosmer, B. C.

Fan and Fan Engine House, Hosmer, B. C.

There are at present about 300 mine cars. These cars weigh 2200 lbs., have a capacity of two tons and have a 4′ wheel base. The Rowbotham cast steel self-oiling, brass bushed wheels are used. They are 18″ in dia. with 3½″ tread, weight per set 581 lbs. Cost about $11 each. Although these wheels must be imported, and have a very high initial cost, they are found to be the most economical wheels to use, because of their longer life and self-lubrication advantages.

It will be noted that, except on the incline, where the grade prohibits their use, compressed air locomotives are employed. They require well built tracks provided with heavy rails; but have many advantages to recommend them. They need, for example, but a single track and are of comparatively low initial cost. No subsidiary line equipment is needed; thus they are free to traverse any road in the mine, and can be readily shifted from one department of the works to another. Their mechanical efficiency is not so low in the long run as might appear from the low efficiency of pneumatic machines generally, for by storage of compressed air at the charging station a more even rate of energy consumption is possible than in the constant cable and electrical power supply, which must be equal to the maximum demand, while the air plant consumes but the average demand.

The tracks are all well built and maintained in good repair; 40 lb. rails are used on the surface and in the main tunnel. 30 lb. rails are used in the gangways. The gauge is 36″; 6″ ties are used and are spaced 2′ 6″ centre to centre. All the tracks have been laid out with even grades and easy curves. This is a precaution that invariably pays for itself many times over, in the subsequent operation. Further, the care in track repair and use of these self-oiling wheels will often make a difference of 75% in track resistance.

The designing of the entire plant, and the elaboration of the various details, have been most carefully undertaken. Elaborate surveys and contour maps were made of the surface, and the location of the various buildings, etc., chosen. The selection of machinery and equipment was thoroughly studied to afford the best economical results and to provide a well balanced plant. The dominating feature of this task is always an endeavour to find a compromise between efficiency and capital outlay.

The result of this may be seen in the power house, which is equipped with a 10-ton travelling crane for the convenient handling of the machinery, and requires but one engineer per shift; also in the boiler house, labour is reduced to a minimum on account of the coal being fed by a conveyor to the chain grate stokers and the ashes drawn off into self-dumping cars, that are hauled out on a trestle by a small winding engine and automatically dumped.

In the case of the fan installation reliability was the first consideration. In fact, in all cases, where the safety of human life was endangered, the utmost precautions were taken, and the most stringent rules are adhered to underground and on the surface to prevent accidents to employees.

The labour question has been very unsettled; but after a strike lasting three months last spring an agreement was entered into with the United Mine Workers of America, under which the mines are now being operated. The agreement provides for the settlement of all disputes without resort to strikes, and distinctly provides for an "Open Shop." This agreement was entered into June 30, 1909, and expires March 31, 1911. See appendix.

The writer gathered from the account given by several English-speaking miners, that in their opinion the strike was uncalled for, and that no advantage was gained.

The town of Hosmer is in two parts: that on the Company's property, and that on the other side of the railway tracks, where the stores, hotels, etc. are located, and many of the miners have bought lots and built houses.

On the Company's property there are: the general office; mess house; three officers' residences, three foremen's houses, a large boarding house; about 88 miners' houses, an hospital and a church.

The houses are all neatly painted, and supplied with water and electric light. Rent $7 to $12 per month.

The water is taken from Hosmer Creek, situated at an elevation of 115′ above the tunnel mouth and 1000′ distant.

An intermediate reservoir is so placed as to give a head for the town of 300′. Wirewound wooden pipe is used for conveying the water. There are 26 hydrants in the town and lower plant and one at the mine.

View from Tunnel mouth, Hosmer, B. C.

Lamp House, Hosmer, B. C.

The conditions of Hosmer have attracted thither a class of miners of settled rather than migratory habits. The unsettled worker is the bane of mine managers in the West, for he disorganizes the mine forces by his frequent "sprees" and is most easily influenced by strike agitators.

The foresight shown by the management of the Hosmer Mines, Ltd., in providing surroundings attractive to the better class of men, many of whom are married, will, no doubt, result in better efficiency in the mine forces as a whole, and in greater freedom from labour troubles.

All the work done on this property by the Hosmer Mines, Limited, has been under the direction of Mr. Lewis Stockett, the General Manager, to whom the writer wishes to express thanks for permission to examine the plant, and for the loan of drawings, etc.

APPEXDIX.

PART OF AGREEMENT BETWEEN DISTRICT NO. 18 UNITED MINE WORKERS OF AMERICA

and

THE WESTERN COAL OPERATORS' ASSOCIATION.

(Which includes Hosmer Mines, Limited.)
June 30, 1909, to March 31, 1911.

SCHEDULE OF WAGES.

Outside Wages.		Hours.
Bottom Man	$2.62½	10
Slate Picker Boys	1.25	10
" " Men	2.25	10
Car Oiler Men	2.25	10
" " Boys	1.50	10
Tally Boys	1.25	10

Outside Wages		Hours.
Teamsters	2.62½	10
Blacksmiths	3.67½	10
Blacksmith Helpers	2.62½	10
Carpenters	3.67½	10
Carpenter Helpers	2.62½	10
Power House Engineers	3.67½	10
" " "	3.15	8
Fan Men	2.62½	12
Hoisting Engineer	2.89	8
Tail Rope Engineers	3.36	8
" " "	3.67½	10
Box Car Loader Engineer	3.15	10
Tipple Engineer	3.15	10
Locomotive Engineer (outside)	3.15	10
" " helper or Switch man	2.75	10
Fireman	2.62½	8
Fireman	3.67½	12
Tipple Dumpers (men)	2.62½	10
" " (boys)	1.50	10
Car Repairers	3.15	10
Breaker Engineer	3.15	10
Fan Fireman	3.15	10
Lampman	2.25–3.15	12
"	2.25–2.62½	8
Machinist	3.15–3.67½	10
Machine Helper	2.62½	10
Ashman	2.25	10
"	2.62½	12
Wiper (man)	2.62½	12
Coupler (man)	2.25	10
Coupler (boy)	1.50	10
Breaker Oiler	2.62½	11
Washer or Tipple O ler	2.62½	11
Breaker Picker Boss	2.62½	10
Timber Framer (men)	3.15	10
Box-car Shovellers (men)	2.62½	10
Breaker Platform Boss, 2.62½; men	2.36	10

Outside Wages		Hours.
Breaker Screen (men)	2.25	10
Dirt Bank (men)	2.25	10
Finisher after box car loader	2.25	10
All other Outside Labour	2.25	10

BEEHIVE COKE OVENS.

Levelling and Drawing (6½ ton charge)	1.00	per oven
Levelling and Drawing (5 ton charge)	.80	" "
Loading into box cars (over 200 tons per month)	.17	" "
Loading into box cars (less than 200 tons per month)	.16	" "
Steam Locomotive Engineer	3.15	10
Motormen	2.89	10
Larrymen	2.25	10
Plasterers	2.25	10
Carters and Cleaners	2.25	10
All other Labourers	2.25	10

INSIDE.

Shot Lighters	3.00	8
Brattice men	3.00	8
" " . . . (helper)	2.50	8
Timbermen	3.00	8
Timbermen Helpers	2.50	8
Tracklayers (Helpers)	3.00	8
"	2.50	8
Motormen	2.75	8
Motormen's Helpers	2.50	8
Locomotive Engineers	2.75	8
Locomotive Switchmen	2.50	8
Drivers	2.75	8
" wet place	3.00	8
"	3.25	8
Couplers (men)	2.50	8
" (boys)	1.50	8
Switch Boys	1.25–1.50	8

Inside Wages		Hours.
Door Boys	1.00	8
Rope Riders	2.75	8
Main and Tail Rope Riders	3.00	8
Pushers	2.50	8
Breakers	2.50	8
Loaders	2.50	8
Miners	3.00	8
Miners (wet places)	3.50	8
Rock Miners	3.50	8
Timber Handlers	2.75	8
Labourers	2.50	8
Cagers	2.50	8
Machinemen (Helpers)	3.50	8
"	3.00	8
Pumpmen	2.50	8
Hoistmen	2.75–3.00	8

HOSMER MINES ROCK TUNNEL.

		Hours	Wet.	Hours
Machine Runners	3.50	8	4.00	8
Machine Helpers	3.00	8	3.50	8
Muckers	2.75	8	3.00	8
Drivers	2.75	8	3.00	8
Miners, Rock	3.50	8	3.75	8
Outside Labour	2.50	10		
Blacksmiths	3.50–4.00	10		
Lumber Framer	3.50	10		
Tracklayers	3.00	8		
Bratticemen	3.00	8		
Hoistmen	2.89	8		
Firemen	2.75	8		

These rates apply only to the present rock tunnels. The tunnels are to be driven continuously, with three shifts of 8 hours each, seven days per week, except the shift from midnight, Saturday, to 8 a.m., Sunday, which will be discontinued for the purpose of changing shifts. The shifts change at 8 a.m., 4 p.m. and midnight.

Hosmer Mines, Ltd.

House rents to remain as at present.
Mine run coal, $2.50 per ton delivered.
Screened coal, $3.00 " " "
Water (outside tap) $1.00 per month.
" (Inside tap) $1.50 " "
Electric Lights—50c per 16 c.p. light per month.
Sanitation—$1.00 per month for each house.
Wash-house—$1.00 per month.

EARLY COPPER MINING IN THE PROVINCE OF QUEBEC.

By JAMES DOUGLAS, LL.D., &c., New York.

(Annual Meeting, Toronto, 1910.)

Sir W. E. Logan, in his report for 1847–48, as Director of the Canadian Geological Survey, refers to copper in the Eastern Townships, and states: "The quantity appears to be too insignificant, in any case, to be worthy of further notice, with the exception of three deposits, where the ore, occurring in veins bearing the character of regular lodes, seems to be sufficient in amount to justify the risk of small careful trial. . . . . One locality is on the 4th lot of the second range of Inverness, in the occupation of Mr. George, where, on the east southeast side of a valley not far from the position which would be in the direct run of the associated serpentines and dolomites of Leeds and Inverness, a vein of opaque white quartz occurs in chloritic and talcose slates, and, coinciding in its direction with the strike of the measure, maintains with the valley a course a little to the north of east. The quartz vein, a mixture of chlorite, presents the thickness of about two feet, and the ore is disseminated in it in irregular patches and lenses, some of which weigh upwards of a pound; but the patches at the outcrop, in the spots experimented upon, are so thin that. notwithstanding the product of the pure ore, which is variegated copper, is upwards of 60%, the whole two feet of the lode do not yield more than 0·74% cwt., which would not give more than 90 pounds of copper in a fathom forward by a fathom vertical."

Nevertheless, it was on this not very flattering showing that the Megantic Mining Company was organized soon after the date of Sir William's report. The Company secured other copper lands

in New Ireland and Halifax townships, and it still exists—the only survivor of the many organizations chartered in those early days.

My personal recollections are of spending my summer holidays of 1850 at these mines in Inverness. I recollect my father finding one of the shareholders reading by the light of a candle stuck into the blasting powder of an open keg, and another calculating seriously on the best way of disposing of his enormous prospective fortune and deciding on patriotically paying off the British national debt.

The copper deposits of Inverness which were then worked resembled the small rich gash veins which were subsequently opened more extensively in Leeds, but which proved in both places too unproductive in quantity to support a mining organization. I do not think the George veins were ever found to be associated with interstratified beds , though further development may show that such connection exists.

Some desultory work was done in Inverness as late as 1856.

The discoveries in the neighbouring township of Leeds had withdrawn attention from those of Inverness. The same promoters and stockholders were interested in both. Dr. Douglas, when in England in the spring of 1853, interested the firm of John Taylor & Sons sufficiently to induce them to send out the well known mining and metallurgical engineer, John Arthur Phillips, to report on this prospect. I have not the report he made to them at that date; but in 1856, when the Quebec and Saint Francis Mining Co. was organized to purchase and work the mine, Mr. Phillips supplied the Company with the following statement:—

REPORT ON THE MINES OF THE QUEBEC AND ST. FRANCIS MINING COMPANY.

"The lands acquired by the Lower Canada Mining Company in the Township of Leeds, county of Mégantic, visited by me in company with Captain F. Kent in 1853, are principally composed of talcose chloritic and micaceous shales, of which the stratification in some localities is disordered, but has a general run approaching east and west. Their underlie, though variable in amount, is almost without exception towards the north.

At Harvey's Hill, to which the attention of the Company has been chiefly directed, a large mass of steatite crops out on the southeastern side of the concession. This substance contains in many places crystals of carbonate of iron; numerous specimens of asbestos were also remarked, and some of the shale beds contain large radiated masses of crystallised hornblende.

The whole of this district is traversed by courses of white opaque quartz, which vary in thickness from a few inches to several feet. These in some instances appear to follow the general direction of the stratification of the country, whilst in others they are evidently true lodes intersecting the surrounding strata at a strong angle.

Such veins in some cases contain copper, specular iron and arsenical pyrites, but are seldom accompanied by any considerable amount of gossan.

The shale in the neighbourhood of these veins frequently contains well-defined crystals of iron pyrites. The general run of the true veins is about 30 degrees east of north, whilst their underlie which is extremely variable in amount, is usually towards the west.

In the Harvey Hill property at least five of these veins occur, and are all more or less spotted with spathose iron and grey copper ore. In addition to the veins above mentioned, and which vary in thickness from eight inches to three feet, this locality exhibits branches of rich copper ore.

On arriving on the ground we found that with the exception of some very ill-directed shoading, no mining operations of any description had been carried on, and that these veins had been merely opened to such an extent as to admit of the extraction of some barrels of ore, which were forwarded to London.

After having completed our general survey of the whole district, we set two men to open on the backs of the branches before mentioned. That called the Brook Lode was thus uncovered for a distance of about ten fathoms, and found to run thirty degrees east of north, with an underlie of one and a half foot in a fathom towards the north-west.

At both extremities of the cutting, which was nowhere above four feet in depth, very excellent stones of grey copper ore were extracted; but towards the middle of the opening from two to three fathoms of unproductive ground were found to occur.

We raised during our operations at this place eight cwt. of very fine copper ore, which was brought down to Quebec and forwarded to London.

This lode, which at the time of suspending our operations was evidently improving in the eastern end both in size and produce, was again cut by an open drift about eighty fathoms south of the point last mentioned.

In this locality, although much disturbed, very beautiful stones of horse-flesh ore are found, it being from this place that the finest specimens sent to England were procured.

About twelve fathoms to the east of the foregoing vein, another rich branch of copper ore was discovered and partially explored previously to our arrival. This vein could be traced for a considerable distance at the surface, and was opened on, for a length of about six fathoms, and a depth of some five or six feet, but although producing in some places exceedingly rich stones of copper ore, we found it very much disturbed and contorted, and regret to say its aspect was not materially improved by the workings we ourselves made upon it.

In addition to the two branches of ore above described, a third was discovered on the Harris Lot, at a distance of little more than a mile to the south-west of the other. This lode, which occurs in a channel of highly magnesian shale, we opened on the back for a distance of about five fathoms and to a depth of eight feet, and in doing so obtained nearly one and a half ton of rich sulphuret of copper, slightly intermixed with crystallized carbonate of iron.

The Harris Lode, as this vein has been called, was found when first opened, to be extremely rich in copper ore, and in fact still remains so; but although it evidently increases in size in proportion as it goes down, the ore last obtained was perhaps more mixed with carbonate of iron. This vein runs nearly north and south, and underlies towards the west, but from the slightness of the dip, together with the contortions to which the enclosing rock has been subjected, it is difficult to determine either its direction or the nature of the underlie it may ultimately assume.

The other lodes in the district have, without exception, remained totally unexplored, since from the limited time allowed for the inspection, we were obliged to confine our operations to

such veins as afforded the most favourable indications. It is however certain that numerous other true veins occur in this district, and that wherever exposed they almost without exception contain more or less copper ore. On the other hand it may be remarked that many bands of spar interposed between the layers of the strata, also afford copper, and that these are in some cases cut off in depth.

The ores obtained from this property in 1853 yielded thirty-nine per cent. of copper, and were sold at the rate of £42. 10*s* per ton.

In the month of September 1855, this district was visited and inspected by Captain Francis Bennetts, who remained a longer time on the ground, and more fully explored the different lodes than had been done two years previously by Captain Kent and myself.

At a distance of fifteen fathoms north-west of the opening on the Brook Vein, Captain Bennetts discovered a lode about twenty inches in width, bearing a little west of north, and on this he extended an open cutting six fathoms in length and eight feet in depth. At the time the workings at this place were discontinued, the lode in the bottom was from fifteen to twenty inches in width, without any perceptible underlie, and composed of a mixture of quartz, carbonate of iron, and grey copper ore.

The lode in this excavation will for a distance of about two fathoms yield one ton of copper ore per fathom. In the other portion of the cutting the lode has been slightly disordered by a small band of killas. There can be but little doubt however that it will again yield ore a few feet beneath the point at which the killas has passed through it.

Nine tons of ore, yielding from thirty-six to forty-two per cent. of copper, were raised from this cutting by two men in the course of four weeks. The Harris Lot, which was also explored, presented a regular lode about one foot in thickness. About two tons of ore were extracted from this vein as a sample, and forwarded to England.

During the time that Captain Bennetts was employed in exploring this property he raised and forwarded to Quebec nearly twelve tons of ore, of an average yield of forty per cent. of copper, and a total value of about £500.

With regard to the facilities for mining, it may be remarked that at Harvey's Hill the whole of the lodes may be cut by a level, at an average depth of about thirty fathoms.

The land in this locality consists of about one-half cleared ground, available for the cultivation of corn and other produce, whilst the remainder is covered by an abundance of timber, well fitted for every mining purpose.

The roads in the neighbourhood are all exceedingly bad, and must in some seasons be quite impassable; but the Grand Trunk Railroad passes within twenty miles of the mines, and considerable facilities exist for the construction of good common roads. The present cost of carrying ores from these mines to the St. Lawrence varies from £3 to £3 10*s*. per ton. Labour, and every manufactured material, is fifty per cent. dearer than in Cornwall. Water power, for the purposes of washing, is to be obtained on the mines.

In conclusion, I would remark, that from the number of lodes already discovered, and the uniform success which has hitherto attended the shallow workings above described, there can be no doubt but that this ground forms a tract of more than ordinary promise, and one which merits a more extensive and systematic trial. I would add that a sum of from £5000 to £6000 will probably be found amply sufficient for opening out the mine.

J. ARTHUR PHILLIPS.

"I beg to confirm the various statements made in the foregoing Report, and to signify my concurrence with the opinions expressed by Mr. Phillips relative to the property of the QUEBEC AND ST FRANCIS MINING COMPANY.

FRANCIS BENNETTS, JUN.

Kensington, February 11*th*, 1856."

The operations of the Quebec and St. Francis Company were sufficiently flattering to induce some gentlemen in London to organize in 1858 the English & Canadian Mining Co., with a capital of £40,000. The history of the English Company was that of many another—each annual report regretted that operations were conducted at a loss, in spite of favourable developments and brighter prospects. Bad roads, costly transportation and

insufficient water supply for ore dressing, were the really valid grounds for the disappointing results. The operations as gauged by shipments of a mine to-day, were contemptibly small.

	Tons	Cwt.	Qrs.	Lbs.	
They were in 1858.....	9	15	0	2	
" " 1859.....	43	7	0	21	Averaging about 30%
" " 1860	104	5	3	0	
" " 1861.....	70	4	1	6	
" " 1862.....	94	17	2	21	
" " " 1863.....	113	20	3	14	.. 26%
And in 1864.....	225	12	3	3	.. 20%
Making a total of - -	671	20	2	11	

The mining ton being 21 cwt., or 2,352 lbs.

But during the administration of the English Company very interesting developments were made. In 1859–60 the value of the interstratified beds was first appreciated, and work was done on them. Mr. Williams, the Superintendent, referring to the bed reported to the Board on 4th February, 1860, says:

"I herewith beg to enclose you monthly report for January, in which I refer to the visit of our eminent provincial geologist, Sir W. E. Logan, to this place. He was much pleased with the works, and thinks we have a great future in our interstratified bed, and considers it a most valuable deposit; in fact, he did not expect to see anything so promising."

And on Feb. 24th he reported:

"We have met with in our interstratified bed, within the last few days, a few isolated crystals of galena, which have given me an assay 72½% of lead and 70 ounces of silver to the ton of lead. The quantity, however, that we have yet met with is so small as to be considered of no value, though I should be glad to see it increase and become one of our important products, which it might be, did we find it in a reasonable quantity."

The ore from the interstratified beds became henceforth the principal source of supply of the English Company. Mr. S. Arthur Sewell, one of the directors, visited the mine, and he reported to the board that:

"This adventure must not be judged of by the rules applicable to those of like kind in this country. To estimate it properly we must take into consideration the almost primeval nature of the district, its distance from any rail or water communication, the scarcity and dearness of labour, the entire absence originally of all accommodation for residence at the mines, and its isolation from any markets where the necessaries of life or the appliances of civilization are procurable.

"With this in view, I must say that during my short stay at the mines I was astonished at the energy which, in a comparatively unsettled country, had pushed forward mining operations of great extent, over a surface of about fifty acres, had erected workshops, built cottages for the labourers, opened stores for their supply, dug reservoirs for water, made tramroads for the transmission of ore from the mines, and last, not least, constructed roads through forests and over swamps for its further transmission to port for shipment."

By 1861 the directors issued a circular, in which they say: "You are aware that the original capital of the company has been all called up. The returns during the present years have increased upon those of 1859, but are not sufficient to allow the payment of a dividend out of profit. The Company's managing superintendent, Mr. Herbert Williams, is now in England, and will be at the meeting to explain the present condition and future prospects of the undertaking.

"The insufficiency of the present capital has been for some time manifest to the directors, and they have been in correspondence with Mr. Williams and the Canadian committee on the subject. Mr. Williams, in a letter dated the 10th October last, gives the following as his opinion of the sum required:—

"'In estimating the additional capital that we may probably require, the time occupied before we realize our products must be considered. It is twelve months since some of the ores now at Swansea left Harvey Hill, and the average, on account of our long winters, cannot be less than about nine months, unless we send some home by way of Portland, or try the Boston market during the winter months. Hence we shall require about nine months' working capital on the average of the year. Presuming we confine our expenditure to the present limited sum of £400

per month, we shall require a sum of £3,600 to carry on the work for that period. I fully trust we shall be able, before the expiration of the nine months, to open out sufficient grey ground to meet our expenditure by the products. Hence the following heads of expenditure will have to be considered by the Board as the estimated capital required for completing the works already commenced, and, I trust, bring the mine, which certainly looks promising, into a healthy condition.

"'General exploration of the Company's lands . . .	£2,000
Buildings	600
Roads.	680
Continuation of Morrison's Adit beyond the period of nine months	750
Working capital for nine months	3,600
Contingencies	370
	£8,000

"In consequence of the above communication your directors have made enquiries as to the best terms on which the above sum may be obtained, and have to report that a friend is willing to furnish the above amount, or such part of it as may be required, for three years, on Debenture Bonds, at 8 per cent. per annum, interest payable half-yearly, to be a first charge upon the property and produce of the mines, after paying working expenses."

But the Report for 1862 opens with a cry of despair :

"At the formation of this Company in the spring of 1858, it was little expected that four years would have elapsed without a sufficient return from Canada to divide as a Dividend amongst the shareholders, but such is unfortunately the case up to this time, notwithstanding the indications of mineral wealth were and still continue to be of a very encouraging nature.

"The Shareholders are aware that the Capital of the Company raised in England became exhausted in 1860, and that by Resolutions passed at an Extraordinary General Meeting, held on the 28th February, 1861, power was given to the Directors to raise on mortgage the sum of £8000, to be taken up as the necessities of the Company might require. The first instalment of

£1000, was received from the late Mr. C. Tilt in May 1st, last, and, subsequently, four other sums of that amount have been received."

A fire at the ore dressing plant interfered with the shipments. The Company sent out a Mr. Tregoning for advice. One of the paragraphs of his report expresses his bewilderment at the departure of our ore deposits from European standards.

"In these slates have been discovered some remarkable 'lenticular masses' and 'interstratified beds of copper ores, and these ores present with the slates in which they are embedded geological features totally different from those of the general mining districts of Northern Europe, but may be considered a type of an extensive cupriferous formation peculiar to this part of Lower Canada, and which there are strong reasons for believing contains a vast deposit of mineral wealth.

"From the appearance of the copper ores when discovered at the surface, they were supposed to be the "out-crops" of what in depth would prove regular and well-defined Lodes, as they did not coincide with the slates either in strike or dip, but after being opened, and yielding some considerable quantities of valuable (copper) ores, they were found to thin away from their centres both horizontally and vertically, and disappear, having assumed the form of lenticular masses, variable in size, and succeeding each other at irregular intervals, and principally composed of quartz, associated with rich ores and bitter spar. In their occurrence and productiveness they will probably be governed by the bands of slates in which they are embedded. The probable average size of these lenticular masses is from 10 to 12 fathoms in length by 5 fathoms in height, and at the centre from 2 to 4 feet in thickness. Many far exceed these limits, and some are much less. They are equally variable in produce, as some have only yielded a few hundred-weight of ore, while others have given several tons. About 300 tons of copper ores have been raised from workings made on these masses, worth about £6,000. Of this quantity about 60 tons, containing from 30 to 40 per cent. of copper, have been obtained from the Fanny Eliza alone, which has been discovered and worked at a depth of 30 fathoms from the surface, by crosscut from Kent's shaft. This valuable discovery proves a singular and important feature of this enterprise, and one greatly

in its favour, and from its appearance and the favourable geological character of the nacreous slates, there is every reason to believe that a greater depth these 'lenticular masses' will be found to increase in size and productiveness."

At this crisis some relief was received by a promise of a sale of the property to a Boston firm of brokers who advanced a forfeitable sum of $20,000. The value of the property was apparently assured by the concensus of so many notable experts, and the sale would probably have gone through but for the financial complications due to the increasing rise in the value of gold in the United States. These negotiations failing, the principal English shareholders tried in vain to float on the English market the London and Quebec Copper Mining Co., with a capital of £100,000. The Englishmen being unwilling to risk more in the venture, some Canadians undertook to pay the Company's debts and to buy out the English shareholders..

The Canadian Company never had adequate means for prosecuting the work. The old dressing floor had been planned after the oldest English models, using hand jigs and disregarding all labour saving appliances. And the water supply was inadequate and variable, being derived from hillside reservoirs. When the English Company was bought out, it was contemplated to build better works on the Palmer River not more than a mile away; but this reasonable plan was abandoned in favour of the leaching method of Messrs. Whelply & Storer. It was a method based on sound chemical principles but carried out by the adoption of as many mechanical complications as perverse human ingenuity could devise to frustrate success. Pulverized charcoal was added to the ore to create an intense heat in a shaft furnace where a most moderate heat was required. Storing pulverized charcoal in a room lined with canton flannel is as dangerous as storing lighted matches, and the mill when it mysteriously caught fire exploded, rather than burned up, before the process had really had a fair trial.

The engine and boilers had been saved, and good concentrating works, provided with Rittenger jigs and designed on his general plans, replaced the Whelply & Storer leaching method.

After the fire in 1867 my father took a lease of the property, undertaking to pay $5,000 a year and to erect a 50-ton concen-

trating mill. His operations under the lease were less unsuccessful than they had been under the old company. The output rose to about 500 tons of concentrates a year, and the revenue nearly covered the actual operating expenses. It was, however, a struggle against penury; and while extravagance has wrecked many a mining enterprise, to the shifts and uneconomical expedients, incident to shortness of funds, not a few other failures have been due.

During this lease the bed which was supposed to run 3½% carried that grade of copper over a comparatively limited area where a series of deep and surface veins affected its copper contents. Beyond this system of veins it carried apparently about 1½%. It could not therefore be worked profitably under the existing conditions with the existing appliances. But the deep veins, especially the Fanny Eliza, yielded an excellent grade of ore and promised so well that a Glasgow organization, The Harvey Hill Copper Co., subscribed a working capital in 1872. The Fanny Eliza Lode and the so-called East Lode had yielded the lessor most of his revenue, but were worked uneconomically by winzes sunk below the upper bed. Both veins looked so promising for permanency that Capt. Whitburn, who was sent out by the Glasgow Company, decided to spend the Company's working capital on a vertical shaft at nearly a couple of thousand feet distant on their strike from the point to which they had been explored. The veins were found where expected; but were barren and the Company treasury was empty. The Company was formally wound up in 1879. The same series of events have I believe been repeated since then—resuscitation, a lingering life, death and burial. And yet I think the property may deserve a better fate.

The ore deposits of Harvey Hill may well have puzzled Mr Tregoning, as they have scant resemblance to those worked in Northern Europe; but in the rocks of the Quebec group and where those same rocks occur in North Carolina and elsewhere, they sometimes carry copper under similar conditions.

At Harvey Hill three beds were met with which, if they extend over the entire hill, would exist at the following depths below the surface at Kent's shaft:—

1. The uppermost bed, cut in grass-shaft No. 2, and from which a great deal of ore has been extracted by the Kent shaft, at 20 fathoms from the surface;

2. The second bed, that lying on the soapstone in Fremont's shaft, which should be at about 60 fathoms from the surface; and

3. The lowermost bed, that met with near the end of the adit, and which should be at about 20 fathoms deeper still, or at 80 fathoms from the surface.

There is, however, no likelihood of these beds being of such great extent, and it is certain they are not of the uniform richness at one time attributed to them.

No exploratory work was done, and no ore was extracted from any of the beds but the uppermost, and as the deeper beds were not encountered in sinking on the chutes of ore in the Fanny Eliza vein, they probably are not of very great extent. The areas of these beds and their copper contents could, however, be very cheaply determined by either churn or diamond drills.

Should any intention to reopen the mines be seriously contemplated, such preliminary exploration work should be done on the beds, as the contribution of ore from the veins, though valuable, would probably be small and the beds would have to be looked to for quantity. The opinion expressed by the Geological Survey that the beds fed the veins is questionable. The impression made on me was rather that the deeper veins fed the upper bed, as its slates were most productive where the deeper veins entered it. These apparently not only enriched it but injected into its slates the constituents which composed their gangue. On the Harris lot, one mile from Harvey Hill, a shallow shaft was sunk on a vein of bitter spar yielding copper glance and visible gold; but neither here nor on any part of the property was what would be considered thorough and judicious development work ever done. Company after company undertook to work the mines with insufficient capital. The cost of mining and concentrating, as compared with modern methods of stoping, on a bed ten feet in thickness, were high. They used to be estimated at:—

Mining, per ton,	$4.00
Dressing the ore (concentrating), per ton,	1.75

The cost of transportation to Quebec was $10.00 a ton, and to Boston, $15.00 a ton. Harvey Hill may now be considered to be on the Quebec Central Railway. The above figures for extraction and treatment might now be reduced to one-third.

But it is doubtful whether any of the mines of the province would be singly productive enough to feed a profitable smelter, and few copper ores or even copper concentrates can bear a heavy transportation charge. If the copper mines of the province are to be advantageously opened, it should be on some principle of co-operation by a strong company.

These copper deposits were, when they were most actively worked, distributed as occurring in "three synclinal troughs."*

The *first* is briefly defined as "the synclinal extending from the Township of Farnham, near Missisquoi Bay, to the Seigniory of Lauzon, on the St. Lawrence. This, where it is traversed by the St. Francis, is nearly or quite separated into two parts by the appearance of the underlying slates. The south-western portion appears to be divided by an undulation into at least two subordinate troughs, thus giving the Roxton and Ely an additional breadth to the exposure of these rocks. The copper deposits of Upton, Acton, Wickham, Roxton, and Durham, occur in this synclinal, while in its north-eastern extension are those of Wendover, Somerset, Nelson and St. Flavien."

The *second* synclinal is described as "extending from St. Armand to the Seigniory of St. Mary, on the Chaudière. In it are the copper deposits of Sutton, Shefford, Stukely, Melbourne, Cleveland, Shipton, Chester, Halifax, Leeds, Inverness, and St. Mary. In its southern extremity, this synclinal is divided into two by Sutton Mountain, and while one part occupies Sutton Valley, the other extends southward into Potton....."

The *third* synclinal is described as "extending from the Owl's Head Mountain on Lake Memphremagog, to Ham, and includes the Stoke Mountains. An extension of this is traced north-eastward to Vaudreuil and St. Joseph, on the Chaudière and beyond it, into Buckland. Between the south-western portion of this synclinal and the second one, is a large area occupied by newer rocks, of the same age as those which limit the belt to the south-east. They include the slates and limestones which occupy the northern part of Lake Memphremagog; and, extending through parts of Oxford, and Brompton, cover a considerable area in the contiguous parts of the Townships of Windsor, Wotton, Ham and Stoke. These unconformably rocks overlie and conceal

* The Geological Survey Report for 1863, page 709.

a large portion of the strata of the third synclinal; but along the eastern limit of this are exposed the copper deposits of Ascot, Ham, and Garthby."

Roughly speaking these three groups of deposits, some of which may be developed into mines, contain the necessary elements of a favourable smelting mixture. In the first group are the calcarious ores of Upton and Acton. In the second the silicious and aluminous ores in the slates of the Quebec group. The leanest are suitable for concentration to a higher grade. The richer would bear transportation to a central smelter. In addition to the ores of Harvey Hill, others of the group worthy of examination are the mines still owned by the Megantic Mining Co., in Inverness, New Ireland, and Halifax; and also the Viger Mine and other mines in Chester and St. Armand counties. The third group would yield the essential element of sulphur, without which economical smelting could not be conducted. Such a scheme would of course require much preliminary study, prudent development work, and then abundant capital for its realization, should the study and development work justify this third step. Singly, the deposits are probably too small to be self-supporting, and their ores are unfit for isolated treatment, whereas consolidated there may be the material for a successful enterprise.

DISCUSSION

DR. A. W. J. WILSON:—It happens that I was sent by the Department of Mines last summer to hold what I might call a post-mortem examination on all these old prospects in the Province of Quebec. I had a list of 525 places in which some of the minerals carrying copper have been found at some time or other—the earliest date being about 1841. In addition to that I had records of some seventy-five other localities. In all I visited about two hundred localities—all old prospects, prospecting pits, and all the old mines of which I could get any record.

NOTE.—Herbert Williams, manager of the Harvey Hill Copper Mines and who did a great deal of expert work during the decade from 1860, 1870, read an interesting paper on copper mining in Canada East, which was published in the Transactions of the Quebec Literary and Historical Society in 1865.

I might say that at the present time in the Province of Quebec there is but one copper mine, the Eustis, in active operation. That happens, however, to be the deepest metal mine in Canada. The bottom of the shaft is about 2,750 feet below the original sills. The present hoist is located between three and four hundred feet beneath the original opening at the summit of the hill.

This summer there were seven prospects on which work was being done. In two or three cases I think the majority of the professional men here would have advised that this work should have been discontinued as soon as they had seen it. In four cases there was some prospect of finding paying quantities of ore.

The Eustis mine, the most important copper mine in the Province of Quebec, has been in continuous operation since about 1885. I had an opportunity of studying that property in detail, spending nearly six weeks at the mine. As far as possible I went through all the old workings and made a survey of them. Many of the old workings are rather dangerous at the present time. and I could not go into them. I have not yet had an opporunity to work out the figures, but I would place the output of that mine roughly at having been about 600,000 tons of ore in the last thirty years. The last annual reports of the Quebec Government give the yearly shipments of that mine as a little above 30,000 tons. In conversation with the manager on the ground, I have learned that their output this year will be well above thirty thousand tons. He said that they eventually expected to raise it to about 50,000 tons a year. The ore they have been shipping is valuable chiefly for its sulphur contents. Both the Eustis and the Capelton mines have been profitably operated from the day they began utilizing the sulphurous contents of the ore. The copper contained in these ores in the Eustis mine from the 19th level to the 24th level has averaged for the last six or eight years less than two per cent. copper; there is also a small gold value, less than 80 cents per ton, and I believe occasionally small silver values are obtained.

With regard to the Harvey Hill mine, I had the good fortune to obtain from Dr. Reid a copy of a report made at the last investigation of the property in the year 1891, at which time all the old workings were pumped out. The report gives many details as regards these old workings, and contains numerous assays. There

is some prospect of finding low grade ore there in quantity, but it will require systematic exploration over a large area, and no person willing to undertake this has yet appeared.

DR. DOUGLAS:—The so-called Eustis mine used to be known as the Orford mine, and up to about 1880 they melted their ores and made a matte. At that time I was in charge of the smelting works in the State of Pennsylvania, and took the contract to reduce those mattes for making nickel and continued doing so until the famous works were built in the neighbourhood of New York; and those works were intended to refine mattes of the Orford mine. Operations went on for some years until the company got into difficulty and I believe Mr. Eustis, being one of the principal shareholders, took as his share of the wreck, the Eustis mines, and the work in New York continued to be called the Orford Copper Works. Since then the Orford Copper Works have of course become very notable as treating mattes from Sudbury. They have now passed into the ownership of another corporation altogether and are largely used for making nickel.

MR. DRESSER:—It affords me pleasure to add a word to this discussion and to express my appreciation of the opportunity of hearing the remarks of Dr. Douglas this afternoon. My information, however, is neither recent enough to be very valuable nor old enough to be interesting as history. There is a point that I would like to emphasize in connection with these ores, and that is their varied characters. There are throughout this district ores that are chiefly chalcopyrite associated with iron pyrites. There are also ores, associated principally with the diabase rocks, that are very often connected with pyrrhotite, the gangue matter of which is high in iron. These ores are also sometimes high in sulphur. In addition to these, amongst those 500 odd localities to which Dr. Wilson has referred there are deposits of the nature of contact deposits principally in limestone, which are associated with basic dykes. The gangue of these ores is principally limestone.

The principal mine of the last mentioned class was the celebrated Acton Mine, that in its time was the largest copper mine producing in the world. This was operated for some ten or twelve years very successfully, but it eventually found its termination. This is one out of a large series of prospects and how thor-

oughly they have been examined I do not know, and I do not know that it can easily be ascertained, but the fact remains that there are these three classes of ores scattered throughout this district.

The possibilities of combination for purposes of smelting thus seem very favourable. On the other hand these properties are held chiefly by small owners; most of the titles were granted by the Crown before any reservation was made except for gold and silver, and consequently the mining rights have passed from one party to another and have been often subdivided, until it is now a matter of dealing with a rather larger number of people in order to secure the rights to a sufficiently large area to warrant important works. These, of course, are difficulties, that are not to be counted as insuperable, but have doubtless been in part the reason of these deposits having lain undeveloped so long since their discovery. The advantages on the other hand seem to be many. Railways now pass near many of these prospects that when originally opened were at long distances from the railway. It seems to me there are very promising opportunities offered for the amalgamation of the mineral holdings over sufficiently large territory, which if approached carefully and developed with that thoroughness which Dr. Wilson has emphasized, would justify the favourable expectations which Dr. Douglas and Mr. Hardman have already expressed.

MAJOR LECKIE:—My experience of mining in the Eastern Townships goes back to almost the middle of the last century. In 1861, Dr. Douglas was then working out with very great skill and industry the problem of treating the ores at Harvey Hill, and his success, of course, was very great, so far as the ore was suited to the old Douglas and Hunt process; but, of course, the advance in what I would call the smelting of ores rather left behind some of those purely chemical methods.

Eastern Canada is greatly indebted to Dr. Douglas for the manner in which the ore was treated at that time. I remember very well about 1862 going down there with a professor from Brown's University and examining some of the veins there. I have often thought that with the improved methods now employed, some of those beds that carry something like two per cent. of copper, might be successfully treated at the present time.

The Acton Mines, the staff of which I joined about 1861 or 1862, to which Mr. Dresser has alluded, was an irregular deposit

in limestone. I remember on the surface one immense boulder weighed thirty-five tons, that averaged thirty-two per cent. of copper. It stood there just like a great egg on the surface of the old limestone formation.

In sinking, at a depth of about 80 feet, we went through the limestone altogether and got into shale, which carried for four or five feet much chalcopyrite and beyond that there was nothing; but I still think that if the ground were more thoroughly prospected with diamond drills, that some very important deposits of copper might be found.

The Eustis mine is certainly a very remarkable one. I reopened that mine in about 1879 or 1880, when on the surface the ore averaged about 3½ to 4 per cent. of copper, and about an ounce of silver for every unit of copper. To-day, at a depth of 3,100 feet upon the slope, it averages somewhere about 2½ per cent. of copper, with the silver contents in similar proportion—an ounce of silver to the unit of copper. The iron pyrites has increased and the ore still retains its market value in this respect. Thus in the earlier days the sulphur averaged somewhere about thirty-nine per cent; now the sulphur runs up to forty-five per cent. and that forms a very valuable constituent of the ore.

Mr. Dresser has alluded in his paper to the chrome iron deposits of the Eastern Townships. I remember in 1861 I mined and shipped 10 tons of ore from a deposit near Lake Nicolet. This ore averaged over 50 per cent. of chrome acid and was about the richest ore ever imported into England.

I have not been in that part of the country now for a great many years.

THE PRESIDENT:—I am sure we are very grateful to Dr. Douglas for his interesting presentation of the early history of copper mining in Quebec. Copper mining in Quebec has certainly accomplished two important things. It aroused Dr. Douglas' interest and it also originated the Orford Copper Company—now a very important organization. Dr. Douglas' address has provoked an interesting discussion and brought to light information indicating that there is a considerable future for the copper mining industry in that province.

RECENT DEVELOPMENTS AT THE GRANBY SMELTER*.

By Frank E. Lathe, Grand Forks, B.C.

The Granby Smelter was built during 1899 and 1900, to treat the low-grade copper-gold-silver ore produced from the mines of Phœnix. The first furnace was blown in on August 21st of the latter year. At the end of 1900 the smelter consisted of bins of 1,000 tons capacity, a sampler plant handling all ore received, and two 44 inch by 160 inch water-jacketed furnaces, and the necessary blowers, shops, offices, and an electrical power-house. The furnaces were charged by a car extending their whole length and entering from the side. Slag was granulated and conveyed by a launder to the high bank near the edge of which the smelter was built. Matte of fifty to sixty per cent. copper was produced, this being sampled and shipped to New York for further treatment.

The ore proved to be nearly self-fluxing, as was anticipated, and the smelting operation was so successful that before the end of 1900 plans were under consideration for the erection of two new furnaces, of like capacity and design to the first, and also a converter plant for the production of blister copper. This work, with the installation of new blowers and other necessary enlargements, was completed two years later. The blister copper, about 99% pure, was consigned to New York; while the converter slag, rich in iron, and containing some copper, gold, and silver, was returned to the blast furnaces, being valuable both as a flux for some of the more silicious ore and for its metallic content. More power being required for the operation of the plant as enlarged than could be supplied from the Granby power-house, additional current was obtained from Cascade, about ten miles distant. This line was operated at 20,000 volts.

*Awarded Commans-Marriott-Frecheville Prize (Paired with H. H. Yuill.)

In the next year, 1904, two other furnaces were constructed, similar in design to that of the first four. At this time also the company's local manager, Mr. A. B. W. Hodges, devised and introduced the present system of end charging, of which a description will be given later. Plans were now made for the erection of a seventh and eighth furnace, and, in order to increase the capacity as much as possible, the experiment was tried of adding another jacket on each side, the length becoming 213 inches. These new furnaces were of somewhat different design, the aim being to make a higher grade of matte than was ordinarily obtained in those previously constructed. To accomplish this the bosh was increased, and made to reach directly to the bottom of the crucible, the width at tuyeres being 48 inches, and the old 5 inch tuyeres which were $17\frac{3}{4}$ inches apart, were replaced by $3\frac{1}{2}$ inch tuyeres set 8 21–32 inches centre to centre. While the improvement in the grade of matte was hardly sufficient to offset the greater difficulty of operation the additional length proved a decided advantage. As soon as this advantage had been conclusively shown the lengthening of the other six furnaces was commenced.

By the time these enlargements were completed, late in 1906, the capacity of the smelter had risen to 3,000 tons per day. Operation was continued without further important changes until the spring of 1908, when experiments were conducted on one of the furnaces. Under the direction of Mr. W. A. Williams, smelter superintendent, this furnace was lengthened by the addition of still another jacket, and the column was deepened. Supports were built for the upper brickwork while the lower part of the furnace was entirely removed and the ground excavated. A cement foundation was then provided, and the furnace reconstructed on the enlarged scale. A thorough trial proved the largely increased efficiency of this furnace (as will be explained later in detail) and a similar enlargement of the others was begun. This work has been but recently completed, and results are proving satisfactory in every way.

While the above-mentioned changes were being made in the blast furnace department other sections of the smelter were also undergoing an enlargement and alteration, to enable them to meet the increased demands upon them. The bins, as already stated,

1. Converter Department, Granby Smelter.
2. Train of blast furnace charge cars.
3. Train of slag cars entering furnace building.
4. End view of bins.
5. Converter slag conveyor and bin.

were originally of 1,000 tons capacity; but after the Great Northern Railway had extended its system from Spokane to the Boundary district and had established connections between Grand Forks and Phœnix, very large additions in bin capacity were made, and in 1907 the capacity was increased to 9,000 tons of ore and 7,000 of coke. In the blowing department new rotary blowers and blowing engines were added, a new steel flue dust chamber with mechanical dust conveyor in part replaced the old brick chamber, and new and larger converters were installed. Power at 40,000 volts was obtained from Bonnington Falls, near Nelson, and about sixty miles distant from Grand Forks. By the time the last four furnaces were constructed the slag dump had extended to the edge of the Kettle River, which runs past the smelter, thus necessitating the substitution of a haulage system. Since that date the slag has been thus removed and dumped while still molten. There was also a gradual replacement of wooden buildings by steel or steel and brick structures. With the exception of the bins and sample buildings the smelter is now practically fireproof.

PRESENT PLANT AND PRACTICE.

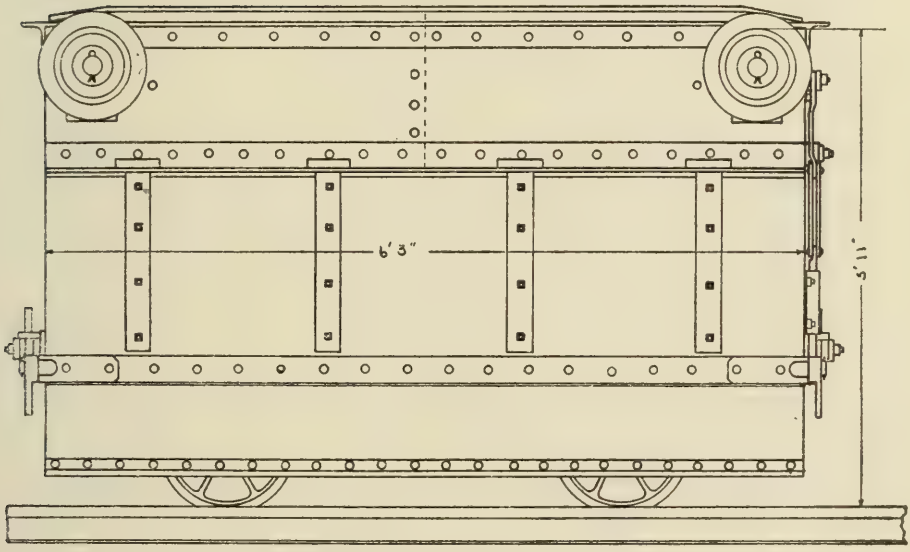
Ore is received from Phœnix in 30 to 50 ton hopper-bottom cars over both the Canadian Pacific and Great Northern lines. The ore from the company's several mines is very uniform in character; but it is found best to reserve certain bins for each ore and charge the furnaces from these in rotation. To facilitate handling, custom ores are stored in the bins adjacent to the samplers. Coke comes from Fernie and Michel, partly in box cars, each having four long slots in the bottom, but mainly in 40-ton steel coke-racks dumping outwards. Clay, from Hendrix Cut, Wash., is unloaded into the end bins near the converters. An accompanying photograph shows these bins discharging at the end, while all other bins discharge into cars running underneath. The capacity of the clay bins is about 500 tons. The bottoms of ore bins slant at an angle of 45 degrees, and are of two thicknesses of two-inch plank. Those of the coke bins are flat, this style of bottom giving a considerably larger capacity, which in the case of coke is very desirable, as well as reducing wear to a minimum. Chutes from parallel rows of coke and ore bins open to the same line of cars underneath, coke and ore chutes alternating.

SAMPLING.

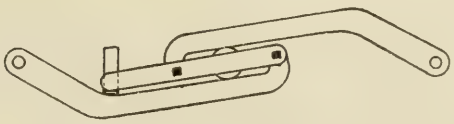
One sample per week is taken of the ore from each of the four crushers in Phœnix, four half-cars being picked at random from a shipment and put through the sample mill. All custom ore is of course sampled. One of the sample mills is used only for quartz ores utilized for converter lining, the other mill handling all Granby ores and the less silicious custom ores. All ore to be sampled is discharged from the bins into ordinary push-cars, and in these conveyed to one of the nearby sample mills. Here the ore is fed into a gyratory crusher that reduces it to about three-inch size, when it is then elevated to the top of the building. Henceforward the treatment is dissimilar in the two mills, the Granby ores being left as coarse as is consistent with accurate sampling, while quartz ores are crushed to less than half-inch to produce a better converter lining material. The mills are alike in the respect that all samplers are Snyder machines, set to take twenty per cent. samples. At the top of the Granby mill the ore is cut; reject—like all succeeding rejected portions—passing to bins from which it is drawn directly into charge-cars, sample passing to a Blake crusher, which reduces to about one-half inch. Another Snyder sampler follows. The sample then goes to rolls set at one-quarter inch. After a third twenty per cent. cut has been made, the crushed ore is quartered by hand to about twenty pounds, and this final sample is sent to the laboratory. In the other mill, as all the ore requires to be finely crushed, two separate operations take place. The first sample cut passes to a storage bin that receives the whole of the initial sample from a shipment. The reject passes over a half-inch grizzly to a crusher and two sets of rolls, samplers being idle, and all ore being elevated to receiving bins. When this operation is completed the chute is opened from sample storage bin to crusher, and the sample undergoes the same operation as that accorded to the former rejected portion; in addition it is cut after each reduction in size. Finally, it is split on a one-inch riffle, and then quartered by hand. This mill can handle forty tons per hour, the total storage capacity for crushed silicious ores being 5,000 tons.

CHARGE CAR

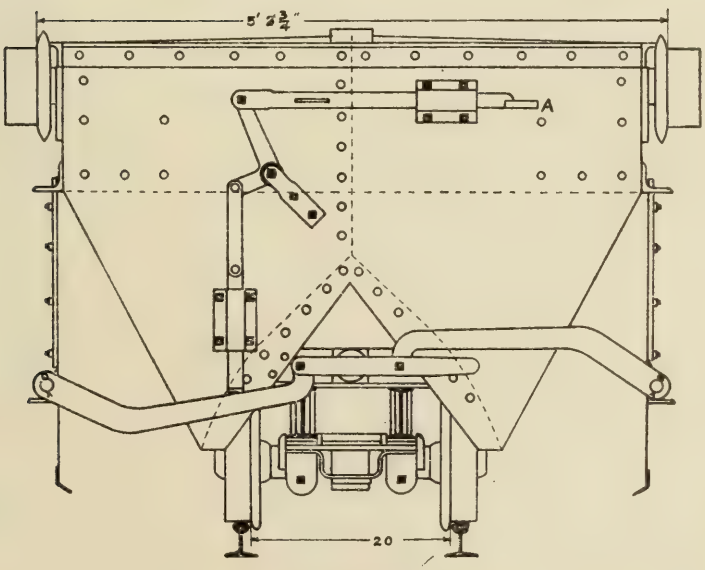
GRANBY CON. M. S. & P. CO., LTD.,
GRAND FORKS, B. C. Tr. by F.E.L.



Side View, Doors Open



Locks, Doors Closed.



End View

METHOD OF CHARGING FURNACES.

Coke and ore are charged separately into the furnaces. A train of three charge-cars, of which drawings are shown, is taken by a 30-horse-power electric locomotive under the bins, and receives $1\frac{1}{4}$ tons of coke. This is weighed and charged into the furnace, and the train immediately returns to the bins for the ore charge. The cars are now filled to their capacity, ten tons for the three, weighed, and emptied into the furnace. This separate charging of coke and ore insures an even distribution of both, and a consequent high fuel efficiency in the smelting operation.

The method of discharging the cars is as described below. As may be seen from the drawings, the cars are supplied with two sets of wheels, the lower for ordinary locomotion, and the upper near the top, for supporting the cars on heavy rails set in the side walls of the furnace when the cars enter with their load. The feed floor rails are disconnected at the mouth of the furnace; but, immediately before entering, the second set of wheels lifts the cars by encountering the slanted ends of the furnace rails, and so passing into the furnace. When the cars are completely inside the furnace the feeder, by means of a long iron hook, pulls the arm marked "A" in the drawing. This releases the locks, and the contents of the cars fall upon the charge below. Usually the locks of two cars are chained together, so that they dump at the same time. In practice the time occupied from the moment when the first car enters the furnace until it is again withdrawn, is from ten to twenty seconds. When the cars are removed the hoppers are again closed and a second trip commences. Complete charges of both coke and ore are made every twenty to thirty minutes to each furnace, and one motor supplies two furnaces. This indicates the speed of operation required. As the cars are divided into four compartments, and the motion given the contents is towards the sides of the furnaces there is no very definite separation of coarse and fine ore. There is a slight tendency, however, for the coarser ore to fall near the centre and at the very outside, the fines occupying the two intermediate positions. This is productive of a very uniform descent of charge all over the furnace. Of course it is easy, in the case of uneven conditions prevailing in different parts of the furnace, to omit the ore charge from one or more compartments in any car, or to add extra coke as may be necessary.

DESCRIPTION OF THE FURNACES.

There are eight blast furnaces, housed in a steel building of 290 feet by 71 feet, along the lower side of which is a shed 13 feet wide. The old blower room is at one end and the converter department at the other, the second and newer blower room being near the converters. To facilitate the handling of ore, the bins parallel the furnace building.

From the history of enlargement of the furnaces already given the present construction may be the more easily understood. Thus the central column shown in the drawing represents the end of the original furnace, and the enlargement was made as shown, instead of taking down the whole furnace and rebuilding with heavier I-beams, etc. Owing to the fact that some of the furnaces have recently shown a tendency to spread, buckstays have been placed along the sides. This has interfered with the piping, which is hence not quite as shown, though the circulation of jacket water remains the same. Recent enlargements have increased the length of furnaces from 213 to 266½ inches, and the depth from 11 feet 9½ inches to 15 feet 8 inches. The width at tuyeres remains the same, 44 inches. As will be noted, the furnaces have two rows of jackets on each side and end, these reaching practically to the feed-floor. Above them is brickwork, ordinary red brick being used for the outside and firebrick for those parts exposed to the greater heat. The whole brickwork is strongly bound with 56 lb. rails, while I-beams, in addition to the buckstays mentioned above, keep the jackets in position. Two outlets are provided for the gases, one leading to the dust chamber and the other, for use in emergencies, opening into the air. Both are provided with dampers.

The jackets are of riveted steel, 7-16 inch and ⅜ inch thick on fire and air sheets, respectively. The water space on upper jackets is 3 5-16 inches, on lower ones 4⅞ inches. All have deflectors to throw cold water to the bottom, and hot water is taken from the extreme top. The lower jackets are 7 feet 6 inches high, and the upper 7 feet 9 inches. There is a good circulation of water, cold water entering the upper jackets and flowing thence to the lower set. This tends to keep a cool top, and prevents undue chilling at the tuyeres, which might attend an opposite circulation. For

this purpose 2,000 gallons of water per minute are required by the eight furnaces or the equivalent of three gallons of water per minute per square foot of hearth area. Water enters at a temperature of from 35 to 50 degrees F., and issues at an average of 140 degrees F.

The blast varies from 24 to 28 ounces, and each furnace takes about 25,000 cubic feet of air per minute.

There is a constant flow of matte and slag from each furnace into its settler through a water-cooled spout. The trap is 5 inches to $5\frac{1}{4}$ inches. As the ore is low in both copper and sulphur a high ratio of concentration is possible, this being usually about 32:1. Moreover, a recovery of 85% of all values is regularly attained. This high percentage is all the more noteworthy when the grade of the ore is considered. The coke consumed is about $12\frac{1}{2}$%, with few extras under ordinary conditions.

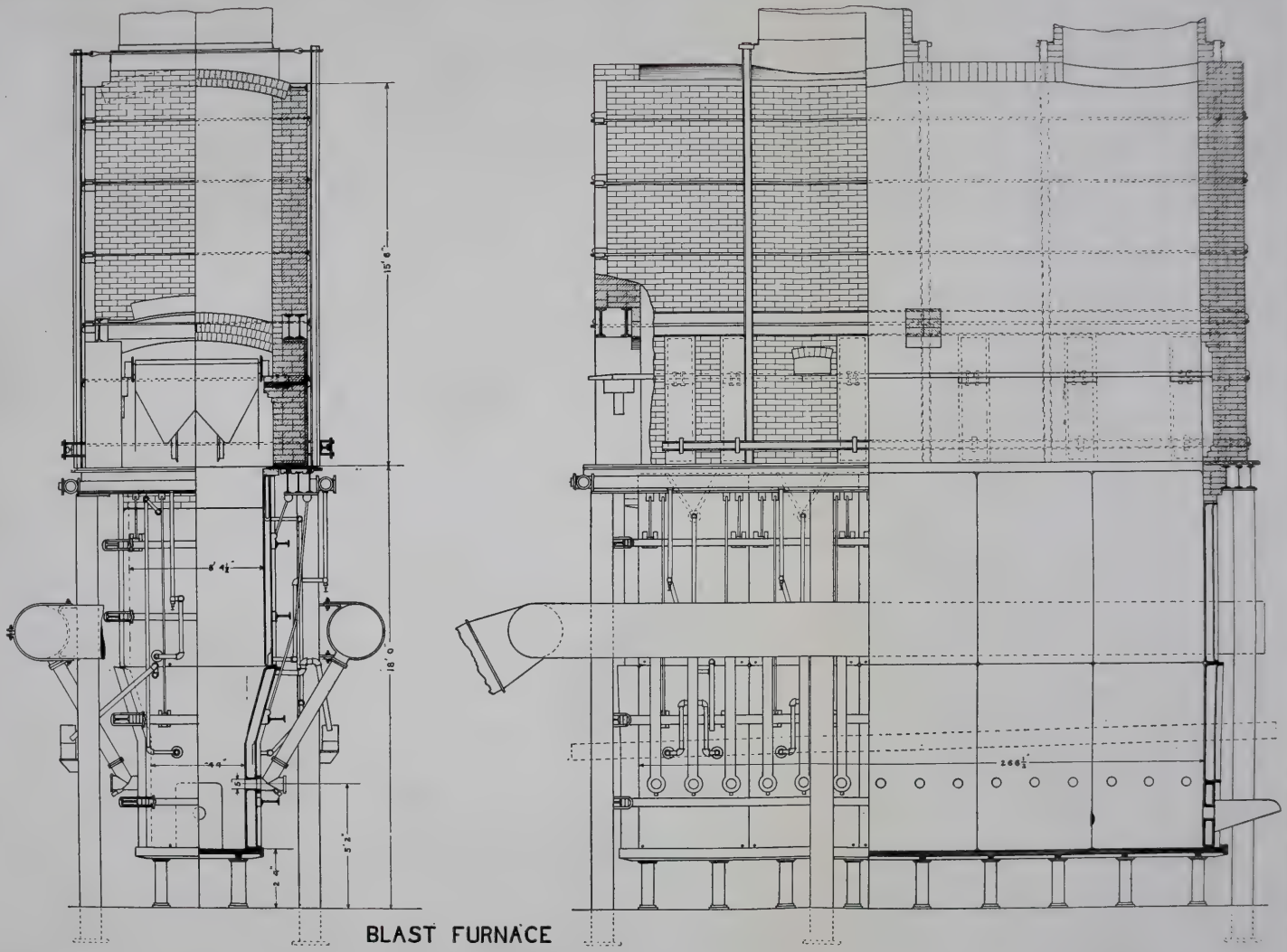
An average analysis of all Granby ores is about as follows:—

SiO_2	35%
Fe	13%
CaO	17%
Al_2O_3	8%
MgO	3%

Copper varies from 1·2% to 1·6%. The "insoluble" in the ore is considerably higher than the silica given above, the latter being determined by fusion. The iron is present as silicates, uncombined oxides and sulphides, while nearly all the lime and magnesia exist as carbonates. Chalcopyrite is the only copper-bearing mineral, and it also carries gold and silver. Of the sulphur about 65% is burnt off, producing a matte of 35% to 40% copper. With the above ore charge the slag will have the following composition:—

SiO_2	44·8%
FeO	19·3%
CaO	21·8%
Al_2O_3	10·2%
MgO	3·9%

In the actual operation, owing to the return of converter slag, the silica is slightly lower and the iron oxide a trifle higher



BLAST FURNACE

GRANBY CON. M. S. & P. CO., LTD.,

GRAND FORKS, B. C.

than these figures. In this slag the ratio of oxygen in the silica to the sum of that in the iron oxide, lime and magnesia is 1·87:1. From the above analyses it will be observed that the ore is easily self-fluxing, and while not quite ideal in composition, the addition of barren fluxes would be attended with loss rather than profit.

Owing to the small percentage of iron in the slag the specific gravity is low—about 3·0. Hence a good separation of matte and slag is obtained. The percentage of copper passing into the slag varies from 0·20% to 0·25%, though some furnaces, operating under ideal conditions, have attained, during a month's operation, even better than this lower figure.

As mentioned above, ore is charged every twenty to thirty minutes, giving a daily capacity of five to six hundred tons per furnace. A maximum of about seven hundred and fifty tons has been reached, equal to nine and a quarter tons of ore per square foot of tuyere area. This is in addition to converter slag and briquettes, though the amount of these is comparatively small. As the work of alteration was but recently completed no figures are yet available for tonnage on eight enlarged furnaces, but seven have smelted forty-two hundred tons in twenty-four hours. An average of four thousand tons per day has been maintained for some time with seven furnaces, and with eight in operation it may reasonably be expected that this figure will be raised to forty-five hundred tons, with a maximum of not less than five thousand.

The greater part of the dust from the furnaces is collected in the new steel flue chamber parallelling the furnace building. This chamber is at a height of about twenty-one feet above the feed-floor level, and consists of a rectangular flue fifteen by thirteen feet, of three-sixteenths and five-sixteenths steel plate. A partition across the chamber, as shown, prevents an undue quantity of gas from going to either stack. The bottom is made up of hoppers, which discharge through nine-inch openings into a trough kept clean by a wire rope drag conveyor. The attendance of one man is required for a short time each day to control the flow of dust from the hoppers, all other movements being automatic. The brick chambers at either end of the steel chamber collect a comparatively small quantity of dust, this being drawn by hand out of openings in the side and conveyed in barrows to the briquetting mill. Here all flue dust is dumped into a receiving

bin from which it is drawn by an automatic feeder to a mixer. After being moistened it is mixed thoroughly, no binder being necessary, and then goes to a No. 2 White briquetting machine with a capacity of four thousand briquettes per hour. This ejects the newly made briquettes on a belt conveyor, which transfers them to furnace charge-cars. They are returned to the furnace without drying. The output of the briquetting mill is about twenty-four tons per day.

Two settlers are used for each furnace. The one next the furnace, and which receives the matte and slag as they flow out continuously, is rectangular in shape, seven feet by five, with corners rounded, and three feet high. It is surrounded by a two-inch continuous water-jacket, the inner plate being three-eighths and the outer one-quarter inch steel. The bed-plate is of cast iron, two inches thick, and removable. Before being used the settler receives a course of fire-brick on the bottom, and is then lined on both bottom and sides with quartz cemented with clay, as for the converters. The life of a settler is usually determined by the rate at which it fills with metallics. When the bottom becomes so high as to materially decrease the capacity of the settler, the latter is replaced by a newly lined settler, while the metallics are removed from the former and broken up with a heavy ball weight. The separation of matte and slag is nearly complete in the settler just described; but a small amount of matte is obtained in the second settler to which the overflow from the first passes. This is smaller, about four and a-half by five feet, but of the same general construction. Once a day it is tapped into a small pit, and the product thus obtained is broken up and returned to the furnaces. The large settler is tapped as often as may be necessary, the height of matte being found by introducing vertically a small iron rod, to which only the slag adheres. From the second settler the slag passes into slag cars standing on tracks of thirty-six inch gauge which run on either side and are used alternately. The capacity of these cars or pots is five tons each, and they are so balanced that when full they are in unstable equilibrium. Small steam locomotives convey them in trains of four to six cars to the edge of the dump. Here a chain is first thrown around the car frame and under the track on which the car is standing, to prevent the car from tipping over when the slag is dumped. The pot is

then released from its upright position and turns on its side, the molten slag pouring out. Being empty the pot is now easily brought back to its original position, so that when the chain is removed it is ready to return to the furnace for another load. Before being refilled each pot receives a wash of clay water, to prevent the solidified shells of slag from adhering to it when dumped. Four locomotives handle all the slag from the eight furnaces, while thirty to forty pots are usually in commission at one time.

Two ten ton electric cranes run the whole length of the furnace building, handle matte, change settlers, remove furnace spouts, etc. One is usually kept in reserve. The matte is taken in five-ton pots into the converter building, where it is received by the forty-ton crane operating there and poured into the converters.

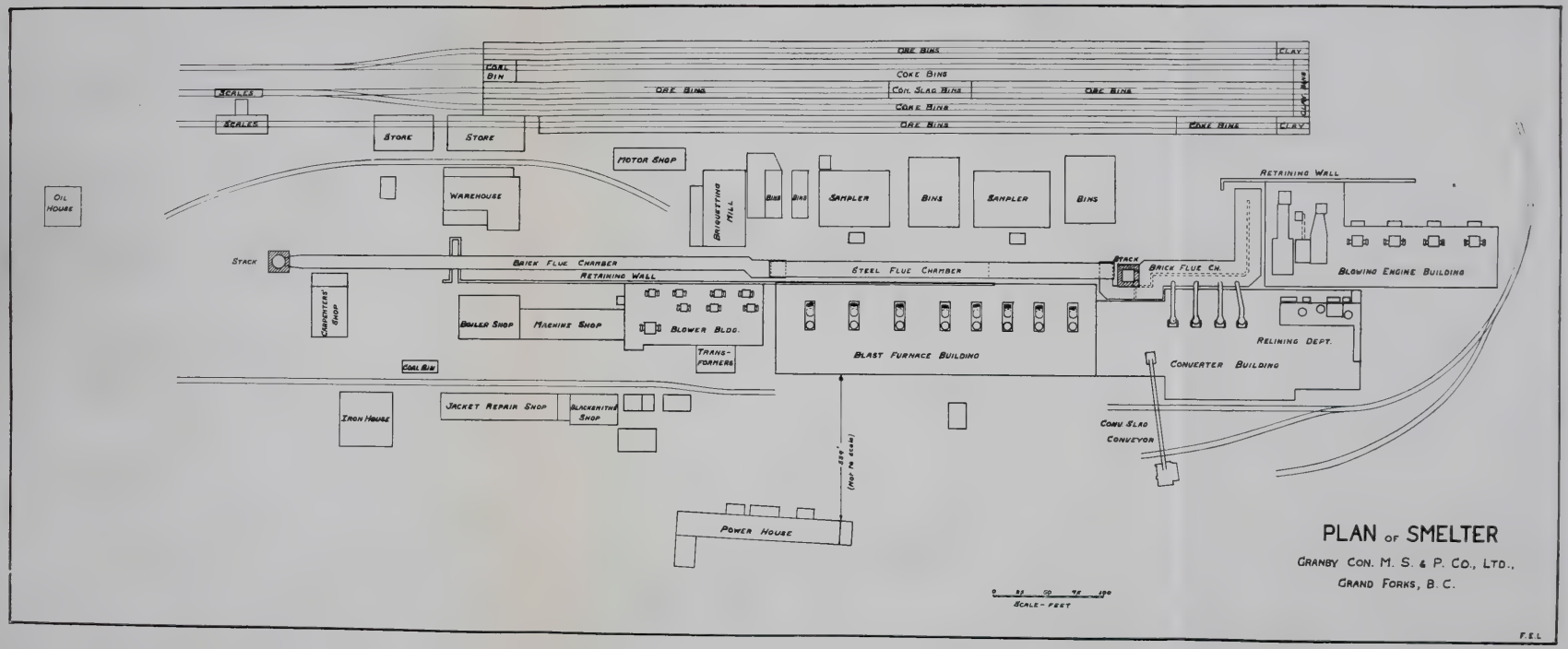
Converter Department.

The converter department is housed in a new steel building 100 by 240 feet. The equipment consists of ten converter shells, 84 by 126 inches, recently purchased from the Power and Mining Machinery Co., three shells 72 by 100, three stands for the large and one for the small converters, moulds for metallic copper, with their trucks, a slag-casting machine with conveyor, and, in the relining department, clay stalls, quartz bins, and three mud mills. The old converters were operated by hydraulic power, while the new ones are equipped with 25 h.p., 220 volt, D.C. motors. All are lined next the shell with chrome brick, some magnesite brick being used around the tuyeres, to protect the metal with a layer of material that will not be readily attacked by matte or slag. Inside this is placed a two-foot layer of silicious ore, cemented with clay, and well tamped. Silica brick is used on the caps. The ores are of several classes, all high in silica and low in sulphur and bases, but containing their values as gold, silver, copper or any combination of them. The Granby Company has no highly silicious ores on its own properties; but has no difficulty in obtaining enough such custom ores, so that no barren quartz is used. There is no definite quantity of matte per charge, as the converters are seldom run to the limit of their capacity. Besides obviating the necessity of a receiving furnace for matte this also enables a transfer of charge to be made from one converter to another, when

the occasion arises. The yearly capacity is fully 40,000,000 pounds of copper. A blast of about twelve pounds per square inch is used, and the copper produced is 98·50 to 99·00% pure. The trucks which carry moulds for the metallic copper are 16 feet long, and run on 44 inch gauge tracks. Each carries eight moulds 33 by 24 inches, outside dimensions, forming a continuous row from car to car. A train of these cars is drawn by a wire rope underneath the converter to be poured. When the last mould is directly under the mouth of the converter it is turned over and the copper is then poured out in a continuous stream, the train being pulled forward as the moulds are filled. Each bar of copper as thus cast weighs about 220 lbs., and after being removed from the mould and trimmed it is weighed and placed in a car for shipment. The pot into which slag has been poured is picked up by the crane and placed in a frame which is gradually tilted by hydraulic power. The slag pours out into the moulds of a conveyor that carries it up an inclined plane, under sprays of water, into a bin from which it is drawn to steel railroad cars. A 5 h.p. motor is sufficient to drive the conveyor, which moves at a speed of about twelve feet per minute. About one hundred tons of converter slag are produced in twenty-four hours. This contains up to forty per cent. of silica, and varying amounts of copper, the remainder being principally iron oxide. It is returned to the bins and thus to the blast furnaces. The photograph of the converter department shows the three large converters, one tilted down for the pouring off of slag, one in full blast, and the third pouring its charge of copper into moulds.

Power.

The blower building recently rebuilt of brick and steel, houses three No. 7 and four No. 8 Connersville blowers, the capacities of which are 12,000 to 14,000 cubic feet per minute each; and one No. 10 capable of delivering 30,000 cubic feet per minute. The small blowers are each driven by a 100 h.p. Westinghouse induction motor, 400 volt, 3 phase, 60 cycle, which, however, carries some overload. The large blower is driven by two 150 h.p. motors of the same type. In the newer building, which is also of brick and steel, and has lately been enlarged, are four blowers similar to the large one in the other build-



PLAN OF SMELTER

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GRAND FORKS, B. C.

F.E.L.

ing, and the three blowing engines supplying air to the converters. These are Nordberg 36 by 36 and Allis-Chalmers duplex 34 and 34 by 36, of 3,700 and 6,000 cubic feet per minute capacity, respectively, both belt driven, and a Nordberg 40 and 40 by 42, with rope drive, furnishing 10,000 cubic feet per minute. Power is supplied to these engines by motors of 200, 300 and 500 h.p., in the order named. In this building are also a small compressor, supplying air at 80 lbs. pressure for tamping the converters, riveting, etc., a 200 h.p. motor generator set, and a pump furnishing water for hydraulic purposes at 200 lbs. per square inch pressure. This pump supplements a gravity hydraulic system which supplies water at 160 lbs. pressure. The Granby power-house, situated immediately below the smelter on the river bank, receives water under 40 to 50 feet head from a flume coming down the bank of the river from a dam about three-quarters of a mile above the smelter. Power is furnished for the pumps, of which there are five, each capable of delivering 500 gallons per minute. against 200 feet head. Of these, two are connected to water-wheels, the other three being driven by motors. Direct current is also supplied at 110 volts for the office and laboratory, and for lighting, and alternating current at 440 volts for use on the works, in all about 900 h.p. In addition to this about 1,200 h.p. is received from the West Kootenay Power and Light Co., and now transmitted at 60,000 volts from Bonnington Falls. This is transformed to 440 volts and then distributed to the smelter. The motor generator set in the blowing engine room supplies the cranes and electric locomotives with direct current at 250 volts.

RESULTS OF FURNACE ENLARGEMENTS.

The enlargement of the furnaces has brought about many changes. It has been conclusively proved in practice that, other things being equal, the tonnage smelted per square foot of tuyere area will be greater for long than for short furnaces. This is true for several reasons. As the end surfaces are the same, any enlargements having affected the sides only, the cooling surface has not increased proportionately to the area. The same applies to incrustation. Moreover, as the percentage of end surface has decreased, so also has the formation of accretions, these having much less opportunity to adhere firmly to the long sides than to the

ends and corners. There being a greater flow of matte and slag from the furnace these will be hotter, and more fluid. The ratio of cooling surface to tuyere area having been reduced so will the amount of jacket water per ton decrease, and with it the loss of heat, thus making a saving of coke. It will usually be found also that the labour required does not increase proportionately to the output. All these points are true for the lengthening of furnaces without deepening, and the Washoe Smelter at Anaconda, Mont., may be given as the most conspicuous example of success attending such enlargements. There are, however, still further and no less important advantages to be derived from the deepening of furnaces, in some instances at least, and these will now be considered in the case of the Granby Smelter.

Other things being equal, the deeper the column of ore in a furnace the less sulphur will be burnt off, the result being a lower grade of matte, and as this requires more iron to unite with the sulphur the slag will be somewhat more silicious. With the deepening of the Granby furnaces the copper in the matte was decreased by from five to ten per cent. and the iron in the slag about one per cent. This meant more matte to handle, additional work for the converters, and more converter slag to be returned to the furnaces, as well as a more difficultly fusible blast furnace slag. Here, however, the disadvantages end.

When the matte is low grade more silicious custom ore will be used for converter lining, and, although this only partly offsets the additional expense, yet the cost of converting, compared with that of the initial smelting, is small per ton of ore treated. Moreover, the converter slag is useful in the furnaces, and often assists materially in righting a furnace that is working badly. It is worthy of notice that however much iron is taken from the blast furnace slag to form a low grade matte all is finally returned to the furnace, the only disadvantage being that some additional silica is returned with it.

The smaller the amount of sulphur burnt off in a furnace the less chance there is of the formation of metallics. This has been a marked improvement on the deepening of the Granby furnaces, especially in the case of the two with the smaller tuyeres.

The present blast furnace slags are more silicious than formerly, as already noticed; but the operation of the furnaces is so

much more even that there is less difficulty under present conditions. A good tonnage has been maintained with 47% silica slags over a period of several weeks, while before deepening there would have been difficulty in preventing the furnace with this slag from freezing. The tonnage attained per square foot of tuyere area is about ten per cent. greater than formerly.

In the old furnaces, with a lower column of ore, much of the heat necessarily extended to the top of the charge, so that the gases on leaving were highly heated. This not only caused a needless loss of sensible heat in the gases, but the high temperature to which the downtakes and the steel flue chamber were subjected necessitated more frequent repairs. By a deepening of the furnace this hot gas has to pass up through a body of cooler ore, to which it imparts a considerable portion of its heat, thus saving from two to three per cent. of coke, and the damage done to the metal with which it comes in contact is much less.

The labour required at the smelter to handle the larger output is practically the same as before, so that a considerable gain is made here.

The greatest saving of all, however, is found in the amount of copper that passes into the slag. The lower grade of matte, greater matte flow, hotter matte and slag, and even running of the furnaces all tend to a more perfect separation of matte and slag, and the danger of the formation of copper oxide is decreased. The percentage of copper in the slag has thus been lowered 0·05%. While this quantity may not seem great at first sight, it amounts in the course of a year to $150,000 or $200,000.

The recent developments as outlined in the preceding pages, involved a large outlay. That they should have been undertaken during the depression of the copper market, indicates the confidence of the management in the company's future. Dividends have now been resumed, and with an ample supply of ore for many years to come, and a thoroughly up-to-date smelter, the company seems to be entering on a new era of prosperity.

THE MINERAL RESOURCES OF THE QUEEN CHARLOTTE ISLANDS.

By J. McLellan, Skidegate, B.C.

The Queen Charlotte Islands form the most westerly portion of British Columbia, and as a group have an extreme length of one hundred and fifty-six miles, with a maximum width (on Graham Island) of about fifty-three miles.

By their position on the direct route of traffic from Prince Rupert to the far East, and also from the variety and extent of their resources, they seem destined to play an important part in the future of this part of western Canada.

The object of this paper is to give a brief account of their mineral resources, so far as at present known, and to this end it seems scarcely necessary to discuss in detail their history or physical characteristics. Those interested in the subject may be referred to the report made by Dr. Dawson to the Geological Survey of Canada in 1878, which, though necessarily out of date in some respects, still remains, perhaps, the most useful general account of the area. A report by Dr. R. W. Ells made in 1905, and also published by the Geological Survey, deals mainly with the coal areas of Graham Island; while the annual reports of the Minister of Mines for the Province of British Columbia, and particularly that for the year 1907, provide more recent information, both in a general way and as regards individual mineral claims and prospects. Briefly it may be stated that these islands form a compact group, the main axis of which lies roughly parallel to the adjoining portion of the mainland of British Columbia, and about seventy miles distant therefrom. The distance from Prince Rupert to Skidegate Inlet, which may be regarded as the geographical centre of the group, is about ninety miles.

It will thus be seen that the islands are rather more difficult of access than any of the others lying off the British Columbian coast, the intervening Hecate Straits forming a dangerous barrier to any except vessels of some size and of a sea-going character. Of late years, however, the Canadian Pacific Railway has maintained a good service with the mainland, and at the present time both this company and the Grand Trunk Pacific have a bi-monthly steamer calling at Skidegate and other ports on the islands.

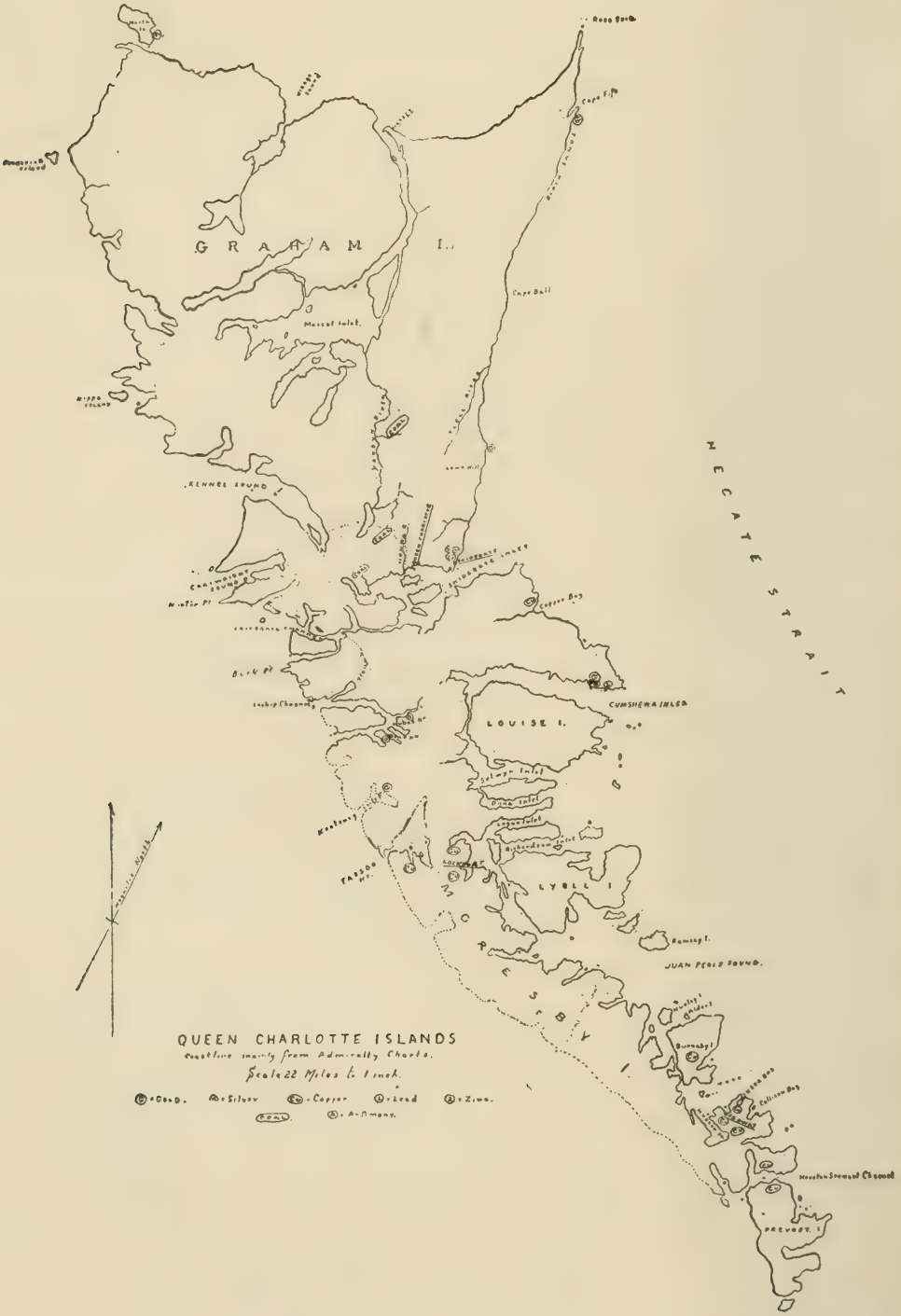
The sketch map accompanying this paper will serve to show the relationship of the various islands composing the group.

The principal harbours on the East and North coasts have been surveyed, and the intervening coast line mapped with a fair degree of accuracy. As regards the West coast, however, the present charts are very inaccurate, and are indeed only of use as fixing the general trend of the shores, and the approximate position of the outlying points, and more important harbours. Dr. Ells' report includes a very useful sketch map of Graham Island, but this also in many respects is only of an approximate character.

It is much to be desired that accurate surveys of the West coast be soon undertaken, as in its present practically uncharted condition it places very serious difficulties in the way of navigation, or of exploratory work of any description.

West and South of a line drawn from Skidegate to Masset Inlet the islands are distinctively mountainous, some of the summits attaining an altitude of over 4,000 feet; but on Graham Island to the eastwards there is a wide area of land which is either gently undulating, or flat and swampy in character.

The dense covering of timber and underbrush which, as a rule, obscures the surface has been a great barrier to prospecting in the past, and it will on this account be many years before much of the ground in the interior is likely to be very closely examined. On the West coast there are rather more frequent rock exposures than elsewhere, and the underbrush is on the whole not so dense. The climate is an open one, with no great extremes either in summer or winter. The rainfall, while not so great as on the adjacent portion of the mainland, is yet considerable, particularly during the autumn months. Even during the summer, heavy rain and wind storms are not infrequent, and there is much overcast and dull, but otherwise not unpleasant, weather throughout the year.


GRAHAM I.
Cape Ball
Masset Inlet
RENNEL SOUND
HECATE STRAIT
CUMSHEWA INLET
LOUISE I.
Selwyn Inlet
Deena Inlet
Logan Inlet
Richardson Inlet
LOCKHART
TASOO
LYELL I.
Ramsay I.
JUAN PERES SOUND
Burnaby I.
Collison Bay
Houston Stewart Channel
PREVOST I.
QUEEN CHARLOTTE ISLANDS
Coastline mainly from Admiralty Charts.
Scale 22 Miles to 1 inch.
Gold.
Silver
Copper
Lead
Zinc.
COAL
Antimony

The snowfall, except on the higher mountains, is not excessive, there being seldom more than a few inches close to the coast. The ground at a low altitude is almost invariably clear of snow before the end of March.

So far as the climate is concerned therefore, there is no obstacle to the prosecution of mining operations all the year round; but for prospecting, owing to its uncertain character even in the middle of summer, it is sometimes not all that might be desired. Geologically, the islands are a prolongation of the mountain axis of Vancouver Island in a north-westerly direction; the older rocks, that form practically the whole mass of Moresby and adjacent islands, being classed by Dr. Dawson as Triassic, but are in at least some instances probably of even greater antiquity. The cretaceous coal-bearing rocks form a belt some fifteen miles wide, extending from Cumshewa inlet in a north-westerly direction to Masset inlet; while on the flanks of these and underlying nearly the whole of the east and north-east shores of Graham Island are found the tertiary shales and sandstones, themselves in many instances covered by glacial drift, and other superficial deposits of sands, clays and gravels.

It is in the older rocks of Moresby Island, consisting largely of contemporaneous igneous material, that most of the mineral outcrops have been found, and to which the attention of prospectors has hitherto been mainly directed. Comparatively recently, however, outcrops of a promising character have been discovered on Cumshewa and Skidegate Inlets, in veins cutting rocks which are probably of cretaceous age. No discoveries of metalliferous ores of any economic importance have yet been made in the Tertiary rocks of Graham Island.

On Moresby and adjacent islands the mineralization is at many points extensive, but the principal outcrops may be classified under four well marked types:—

(A). *Magnetite iron ores with varying amounts of copper pyrites*, occurring in veins and masses at and near the contact of limestone with igneous rock, principally diorite. Many of the ore bodies are entirely enclosed in the igneous rock, but limestone is usually not far distant.

Examples occur at the Ikeda Bay mine and elsewhere on the south end of Moresby Island, and at Tassoo Harbor on the west

coast. It was the discovery of ores of this character on Moresby Island in 1905, that initiated the present interest in the mineral possibilities of the islands, and in that and subsequent years a great many claims were located. The fall in the price of copper, however, came at an unfortunate time for the progress of the camp, and to the present only one property, the Ikeda Bay Mine, has attained to the shipping stage. The results of development in one or two other instances have not been so satisfactory; but the work done is as a rule not sufficiently extensive to prove the worth or otherwise of the properties on which it has been prosecuted.

The ores in character vary from a coarse grained, and in some instances very pure, magnetite, carrying little or no copper bearing mineral, to a sulphide ore consisting of almost clean chalcopyrite. Magnetite, however, is nearly always present as an important constituent of the ore, which also sometimes includes more or less altered masses of the crystalline rock in which the veins occur. The copper pyrites is found irregularly disseminated through the mass in strings and bunches, and in exceptional instances in a fine granular form.

Several thousand tons of ore of from six to fourteen per cent. copper have been shipped from the Ikeda Bay Mine.

In ores of this type the gold and silver values are as a rule quite subordinate, and appear to be roughly proportional to the percentage of sulphides present. Selected ore rarely assays more than $6.00 gold and five ounces silver per ton, while average values are much lower.

Free gold is occasionally found in small secondary veins and stringers intersecting the sulphide ore bodies, but is of no economic importance. One occurrence of this kind observed by the writer was on a claim near Houston Inlet, an irregular mass of magnetite with low copper values being here intersected by a small vertical quartz vein a few inches wide. Specimen gold ore was obtained from this vein, but within a foot or two of the surface only, the quartz carrying no values outside the limits of the magnetite ore body.

The purer magnetites of these islands may at some future period be of value as an iron ore, since many of the outcrops are of considerable extent; but as no work beyond a little surface stripping has yet been performed on such exposures, not even an approximate idea can be formed as to their true value to this end.

(B). *Altered Diabase impregnated with small quantities of copper minerals, chiefly Chalcopyrite and Bornite,* the whole forming a copper ore of low grade but very large extent on surface.

This type of ore body, so far as known, is confined to the neighbourhood of Lockport on the East coast of Moresby Island.

The writer has not personally visited this camp, but from the reports of the Provincial Mineralogist and other competent observers it appears reasonably probable that it may become a large producer of low grade copper ores.

The mineralized belt on the Swede Group, and other claims, is on surface at least 250 feet wide, and is reported to carry from one to three per cent. copper, the gold and silver values being insignificant. The ore is admittedly low grade, but the facilities for cheap mining are almost ideal, and it is believed it can be handled at a good profit if worked on a sufficiently large scale.

(C). *Gold and silver associated with iron pyrites, galena and zinc blende,* in a quartz gangue, in fissure veins cutting both sedimentary and volcanic rocks of cretaceous and older formations. Examples of this group are found on the north shore of Cumshewa Inlet on Moresby Island, and on the north side of Skidegate Inlet on Graham Island. The intervening section and that farther north on Graham Island have scarcely been prospected at all as yet, the comparatively low and densely timbered character of this area having tended to discourage prospectors.

From the character of the outcrops and the grade of the ore, however, it is the writer's belief that this belt is worthy of much more careful attention than has hitherto been devoted to it. Only surface cuts and stripping have so far been performed on any of the outcrops, and no information as to the behaviour of the ore bodies with depth is yet obtainable; but in several instances the veins have been proved to be persistent for considerable distances along the strike, and the prospects for deep development seem therefore promising.

On Cumshewa Inlet the veins occur in a black slate, and are from a few inches to four feet wide, the ore carrying high values both in gold and silver. At Skidegate the values are almost entirely in gold. The country at this latter point is a fine grained volcanic agglomerate with apparently intercalated sheets of a dark green crystalline rock, probably a diabase. The gangue is mainly

quartz, but also includes some of the altered country. Both at Cumshewa and Skidegate fine colours of free gold can be obtained by careful panning of some of the surface ores. At Skidegate this free gold is apparently associated more closely with the galena than with any of the other sulphides. The ores at both points are of a type suitable for concentration, while the conditions for cheap mining and transportation as elsewhere on the islands are excellent.

(D). *Free milling gold ores* in a quartz gangue, occurring in fissure veins cutting volcanic tuffs and breccias.

Ores of this type have been found at three points on the west coast of Moresby Island.—Gold Harbour, Mudge Harbour, and Kootenay Inlet.

The Gold Harbour area is interesting historically, as one of the first discoveries of gold in British Columbia was made at this point. This was by the Hudson's Bay Company so long ago as 1852, samples of free gold having been brought to them from the islands by Haida Indians. An expedition was organized and proved a profitable venture, but no accurate information as to the amount of gold extracted is now obtainable. Estimates vary from $5,000 to a very large amount. At any rate the ore proved of a pockety character and the district was soon abandoned. The old workings consist of an open cut some thirty feet long, close to the water's edge and parallel to the coast line of the harbor. The deepest part is only about twelve feet from surface. This work has exposed an irregular quartz vein, almost vertical, and varying in width from a mere seam up to eighteen inches, the vein filling being a hard milky white quartz, with a very small proportion of iron and copper, pyrites, and carrying gold values under $2.00 per ton. No high grade ore is now visible at this point.

North of this another small, but at places very rich, vein, was discovered about three years ago, and development is now being carried on. The gold is quite free and often visible to the naked eye, but is somewhat erratic in its distribution, rendering it difficult to obtain a true estimate of value by assaying. The writer is at present installing a three stamp prospecting mill on this property with a view to experimental testing of the ore during further development.

On the north side of Mudge Harbour and on Kootenay Inlet other finds of free milling ores have recently been made, that both in type and mode of occurrence appear very similar to that at Gold Harbour, and the district as a whole seems worth further prospecting. The above four general types include practically all the metallic ores found on the Queen Charlotte Islands, but some other metals are known to exist in small quantity. Native arsenic has been noticed on one of the small islands near the south end of Moresby, while a deposit of antimonite occurs on the shore of North Island. Alluvial deposits do not appear likely to be of much economic importance. 'Colours' of gold are found in several of the streams and have been noticed personally by the writer on the Tlell river, and on one of the creeks flowing into Cartwright Sound; but in no instance so far observed have the gravels been proved rich enough to pay for working.

Black and ruby sands carrying fine gold are found at intervals along the eastern and northern shores of Graham Island, from Lawnhill to Masset Inlet, and have been worked successfully in a small way in the neighborhood of Cape Fife. The gold is not exceptionally fine, but the grains are much flattened, and being associated with large quantities of magnetite and other heavy minerals, has proved difficult to save. The sands have been derived from the action of the sea on the high banks of clays and gravel which line this portion of the coast. These banks are largely of glacial origin, and their materials may thus have come from a considerable distance; but it seems probable that the gold has its origin somewhere in the interior of Graham Island. Some prospecting has been done with a view to proving this, but so far without success.

While not strictly speaking within the scope of this paper, it is hardly possible to omit some reference to the coal seams found in the cretaceous rocks of Graham Island, as the success or otherwise attending the development of these must exert a profound influence on the industrial future of the whole area.

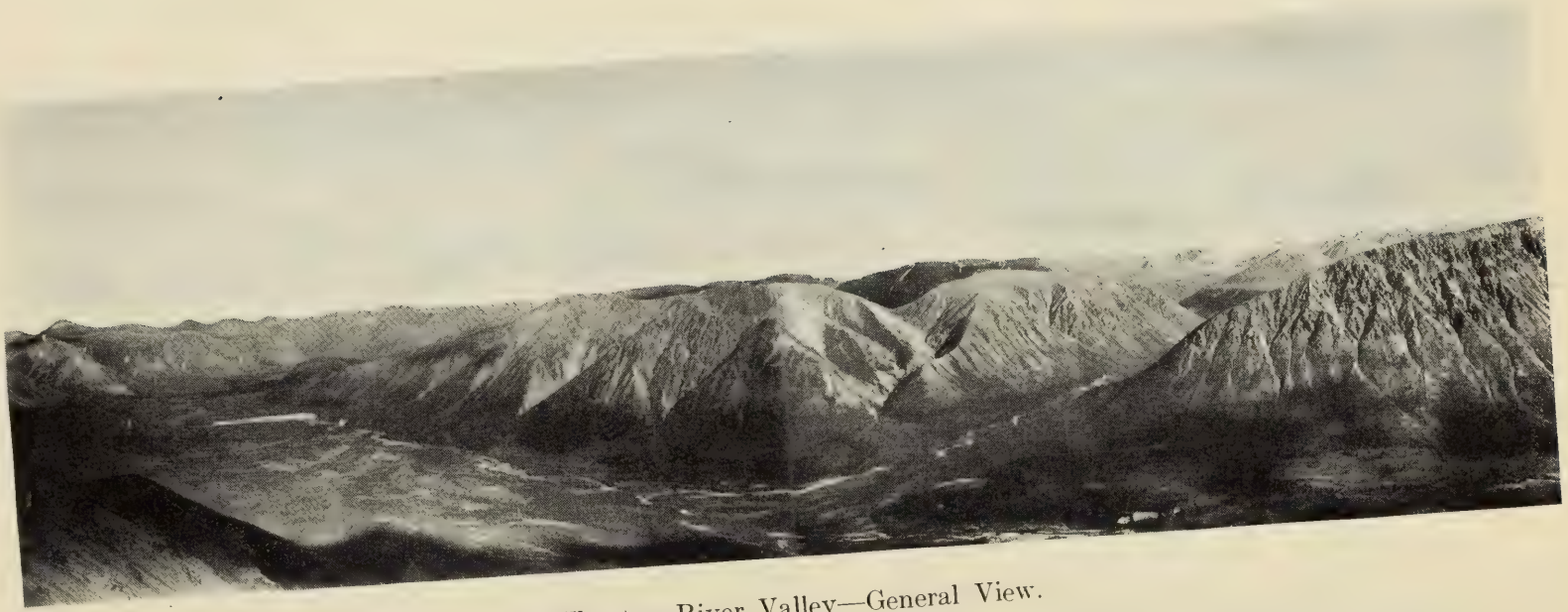
In this connection but little can be added to the particulars given in Dr. Ells' report. That promising outcrops of bituminous and semi-anthracite coal occur in the interior of Graham Island is certain; but the regularity and extent of the seams must be regarded as unproven until more development has been done. In a

country covered by such a dense surface vegetation, the tracing out of the structure of the coal area is necessarily difficult, but the showings are sufficiently extensive to justify very considerable expenditure on development, and it is expected that this will be undertaken in the near future. Boring is now going on on the east side of Masset Inlet, but with what result is not yet definitely known.

From the above brief description it may be gathered that the Queen Charlotte Islands are still only in the initial stages of development, and it would be somewhat rash as yet to express any very definite opinion in regard to their future as a mining country.

The mineralization of the group, and particularly of Moresby and adjacent islands, is undoubtedly extensive, and of a somewhat varied type; while the conditions for cheap mining are quite unusually favourable. Practically all the locations being within a few miles of deep water with many excellent and sheltered harbours reasonable transportation charges are assured to any point.

Notwithstanding all this, the activity in mining that began some three years ago has not been well maintained; development of some of the properties having shown the ore to be both of lower average grade and more erratic occurrence than had been hoped for. This work, however, has been confined very largely to one type of ore-body (the copper bearing magnetites) and even on this mainly to one district, and as a rule neither in extent or character has been sufficient to prove or disprove the value of the ore occurrences. It must be remembered, also, that in such a densely timbered area, anything like exhaustive prospecting is difficult, and it is, therefore, improbable that more than a small fraction of the actual mineral outcrops has yet been discovered. Hence the present inactivity is evidently only a temporary phase, and it is unlikely that a country possessing such great advantages for cheap and profitable mining will long lack the capital necessary for its development.



Wheaton River Valley—General View.

THE WHEATON RIVER ANTIMONY DEPOSITS, YUKON TERRITORY.

By D. D. Cairnes, Ottawa, Ont.

(By permission of the Director of the Geological Survey).

(Annual Meeting, Toronto, 1910).

As antimony in any considerable economic quantity is of somewhat rare occurrence, not only in Canada, but throughout the entire North American continent, it is believed that a description of the comparatively recently discovered deposits on the Wheaton river, in the southern portion of the Yukon territory, will be of interest to members of the Canadian Mining Institute.

These Wheaton river ores are the only ores of antimony yet discovered in the Yukon territory, and are limited in their occurrence, so far as ascertained, to a single locality perhaps two miles wide by three or four miles long, embracing Carbon and Chieftain Hills. These hills lie on opposite sides of, and face the Wheaton river at a point thirty-two or thirty-three miles above where it empties into Lake Bennett. They are also not more than ten or twelve miles north of the 60th parallel—the British Columbia-Yukon boundary. While prospectors have reported discoveries of antimony ore at localities a few miles to the west or south-west of Chieftain Hill, the writer has had no opportunity of forming an opinion concerning the value of these alleged finds.

During the past summer, a waggon road of good grade was completed for a distance of about 30 miles, from Robinson on the W. P. & Y. Railway to Carbon Hill. Robinson is only 78 miles distant by rail from Skagway, which has regular steamer communication with Vancouver and Seattle. Hence the locality in which these deposits occur is readily accessible.

The antimony ores were discovered during the summer of 1893 by two prospectors, Frank Corwin and Thomas Rickman, who located a number of claims on Carbon and Chieftain Hills and also prospected the properties by trenching. After completing this work the men returned to Juneau and reported their finds which they believed to be of considerable value, to the manager of the Treadwell mines. Before, however, any steps had been taken to investigate the matter, both prospectors died suddenly without disclosing the exact whereabouts of their discoveries; and although many attempts were made, Carbon and Chieftain Hills remained unlocated until re-discovered in August, 1906, by Mr. H. E. Porter who immediately staked out eighteen claims. This resulted in a "stampede" to the vicinity and as a consequence a great number of claims were thereafter located. A large proportion of these are still held; but on only a few has any work, other than legal assessment, been performed.

TOPOGRAPHY.

The district in which these deposits occur is situated near the western edge of the Yukon Plateau, not more than five miles from the typical mountains of the Coast Range. There is, here, however, no sharp line of demarcation between plateau and mountain provinces, as the two grade into one another so that, topographically, it is difficult to say where one ends and the other begins. Both plateau and mountains occupy an area which during the interval between the Eocene and Pliocene times stood at a much lower elevation than at present. This area was subjected to subaerial agencies, the most effective of which were stream and river action, until it was reduced to an almost level surface but slightly above the elevation of the sea. At the termination of this long period of erosion, during which the land must have been in a state of relative stability, a nearly featureless plain was produced and only occasional residuary peaks and ridges remained standing above the general level.

In late Pliocene, or early Pleistocene time, this even surface, or peneplain, was gradually raised. The amount of uplift was greater along the western portion of the territory now occupied by the Coast Range, than farther east in the present central plateau area.

Erosion thus received new life and energy, and the larger streams, such as the Wheaton river, commenced deepening their channels in the uplifted surface. The effects of stream-action, in this respect, were accentuated by glaciation. The main ice-masses occupying the principal depressions were effectual in straightening the courses and reducing the slopes of the valleys, at the same time widening and lowering their floors. The valleys thus produced were wide, deep and steep-walled. The presence of the ice, moreover, assisted in filling up the valleys to considerable depths, with silts, sands, gravels, and boulder clay.

The effects of erosion and uplift, followed by further erosion and glaciation, are strikingly in evidence in the vicinity of Carbon and Chieftain Hills. The tops of these hills, being portions of the old peneplain, are flat-topped or gently undulating; and from any of the higher points of this upland, the summits of the surrounding district are distinctly seen to have originally belonged to the same surface, the original continuity being now interrupted by numerous valleys extending in all directions.

The wide, steep-sided valley of the Wheaton river intersects this plateau and separates Carbon from Chieftain Hill. The elevation of the upland varies from 2,700 to 2,800 feet above the Wheaton valley, which in turn is here 3,400 feet above sea level. The antimony deposits are located at the summit and along the west face of Carbon Hill, as well as on the east slope of Chieftain Hill.

TIMBER.

The district is sparsely forested. Trees and shrubbery grow in the valley flats and along the slopes up to a height of 400 or 500 feet above the Wheaton valley. The only trees of any considerable size are the white spruce (*Picea alba*), black pine (*Pinus Murrayana*), and balsam fir (*Abies subalpina*), of which the spruce is by far the most plentiful. Some good groves of the latter, straight and well grown, were noted; although the individuals were seldom larger than 12 inches in diameter at three feet from the ground. Black pine is occasionally found interspersed with the white spruce or, at times, forming separate groves. The fir is generally found on the slopes near timber line. These latter species have seldom more than a 10-inch stump. Willows (*Salix*), dwarf birch (*Betula glandulosa*), Aspen poplar (*Populus tremu-*

loides), and balsam poplar (*Populus balsamifera*) cover a considerable portion of the valley and are found on the majority of the sidehills to an elevation of 4,000 feet above sea-level, above which altitude shrubbery or trees rarely exist.

In the Wheaton valley between Carbon and Chieftain Hills and along the lower slopes of these hills, there is sufficient timber of a desirable quality for all mining purposes, including cabin building, etc., to last for many years to come, even should mining be extensively carried on.

CLIMATE.

The climate of the Southern Yukon territory is similar to that of many districts in British Columbia and other northerly, but prosperous, mining camps; and in mining the difficulties are very little greater here than in more southerly localities. Thus all outside and surface operations may be continued during at least six months in the year. Furthermore, the great amount of daylight in summer in this northern latitude is a favourable condition. On the other hand, the ground in many localities is frequently frozen to varying depths; but this only interferes with mining operations when conducted at or near the surface.

The rivers generally are navigable early in May; but the ice remains as late as the first week in June on some of the lakes. Stretches of slack water freeze over any time after the middle of October; but during some seasons the rivers remain open until late in November.

GENERAL GEOLOGY.

A considerable variety of rocks, chiefly schists, granites, grano-diorites, sandstones, tuffs, conglomerates, andesites, andesitic tuffs, basalts, rhyolites, and rhyolitic tuffs, occur in this district These are overlain, in many places, by Quarternary superficial deposits.

The oldest formation outcropping on Carbon or Chieftain Hills, forms the extreme north-east corner of Chieftain Hill, and consists of chloritic and greenstone schists belonging to the Mt. Stevens series of pre-Devonian age.

TABLE OF FORMATIONS.

System.	Formation.	Lithological Character.
Quaternary.....		Gravels, sands, clays, soil, muck, ground ice, etc.
Tertiary.....	Wheaton River Volcanics.....	Rhyolites, tuffs, breccias, etc.
	Carmack Basalts...	Basalt dikes.
	Chieftain Hill Volcanics.....	Andesites, tuffs, and breccias.
Jura-Cretaceous...	Tantalus Conglomerates.....	Conglomerates, sandstones, and shales.
	Laberge series.....	Sandstones, shales, etc.
Jurassic.....	Coast Range Intrusives.....	Granites, grano-diorites, and diorites.
Lower Paleozoic?..	Mt. Stevens series....	Chloritic and greenstone schists.

More recent than these are the Coast Range intrusives, consisting of granites, grano-diorites and transitional types. These form part of the Coast Range batholith that cooled in late Jurassic times, and constitute the most prominent formation in this locality. They outcrop over a great part of the surface and underlie the most of the district. These rocks are generally fresh and unaltered in appearance, and are prevailingly greyish in colour. In places, they are quite porphyritic, and feldspar phenocrysts $1\frac{1}{2}$ to 2 inches long were frequently noted. The greater number of the mineral veins occur in these rocks.

Overlying the granitic rocks are those of the Laberge series consisting here chiefly of sandstones and shales of Jura-Cretaceous age. These outcrop over a portion of the top of Carbon Hill, and consist, for the greater part, of coarse, reddish sandstones and reddish to greenish shales.

Superimposed upon the Laberge beds are the Tantalus Conglomerates, consisting chiefly of cherty and slatey conglomerates. In other parts of the southern Yukon Territory these contain seams of coal, but no coal has, up to the present time, been found on Carbon Hill or Chieftain Hill. This may be attributed to the fragmentary character of the conglomerate series in this locality.

The Chieftain Hill volcanics in many places invade as well as overlie all the above mentioned formations. These consist

of an extensive series of andesitic rocks, which, in some places, occur chiefly as dykes, together with andesitic tuffs and volcanic breccias; but, in others, form important stock-like masses, as well as sheets and flows. They vary from mica-andesites with greenish-grey, to reddish groundmasses (in which are well defined plagioclase and biotite phenocrysts) to fine-textured, dark green, augite-andesites. In places, as on the west side of Carbon Hill, they contain considerable iron, the leaching of which has caused the rocks to become disintegrated and heavily stained with iron oxide. A number of antimony veins occur in these Chieftain Hill andesites.

In a number of places dykes of a dark and apparently very recent basalt occur, cutting the above formation. These represent the Carmack basalts in this district.

The Wheaton River volcanics, are younger than the Carmack basalts and chiefly consist of rhyolites, tuffs, and breccias. These occur as dykes cutting all the other consolidated rock formations of the district at numerous points, and also exist as sheets, flows and accumulations, overlying considerable portions of the plateau surface. A thin layer covers the greater portion of the summit of Chieftain Hill. These rocks are prevailingly light yellow in colour, becoming reddish in places, in consequence of the oxidation of small particles of contained iron ore. They are generally soft, decompose readily due to weathering, and break, as a rule, into thin slabs.

The Wheaton valley is floored with glacial deposits that cover its lower slopes. The channel of the river is entirely in these gravels, sands, and silts. Overlying these Pleistocene deposits, are the recent accumulations, made up of fluvial and littoral sands, gravels and silts of the present streams, ground ice, muck, volcanic ash, and soil, that form a thin mantle over the greater part of the surface.

ECONOMIC GEOLOGY.

Classification.—The Wheaton river antimony deposits are of a rare type, and occur as fissure veins, chiefly in granites and andesites.

Looking up the Wheaton River Valley.—Carbon Hill, as viewed from the north-west, is indicated by an arrow.

View across the Wheaton River Valley, showing Chieftain Hill (indicated by an arrow) with the mountains of the Coast Range behind.

For purposes of clearness, the writer presents the following classification of antimony ore deposits:—

I. Ore-containing cavities, chiefly fissure veins.

a. Those of value chiefly, or entirely, for their antimony contents.

b. Those notably gold-bearing, the stibnite being auriferous.

c. Those containing values in both antimony and silver.

II. Metasomatic replacements:—

Most deposits of antimony ore belong to Class I. Those grouped under Class II occur chiefly in limestones, and have only been found in a few localities, the chief of which are:—

In Westphalia* at the Casparizeche mine near Uentrop, and at the Passauf mine near Nuttlar; in Algeria, at Sidi-Rgheiss** in the south-west part of the province of Constantine; in Tuscany, the deposit of Cetine di Cotorniano;† in the province of Servia—in Krupanj‡; and in Mexico, at Sonora.¶

With few exceptions, the ores of Class I belong either to division (*a*) or (*b*). In the one case (*b*), the ores are mined chiefly for gold, the antimony values being negligible. In the other case (*a*), the ores are worked chiefly, or entirely, for their antimony contents. The veins of these two types are, however, closely allied and grade into one another. Those of division (*a*) represent merely the extreme, or gold-poor, facies of the deposits of Class I. The only antimony deposits in Canada at all extensively mined

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* E. C. Buff, "Uber Gangbildungen welche eine lagerartige Enstehung zu haben scheinen (Spiessglanzerz auf der Casparizeche): Karstens Archiv f. Min, 6 Bd., 1833, S. 439. A. W. Arndt, Uber den Bergbau auf Spiessglanz am Silberberge bei Arnsberg. Elberfeld, 1834.

**. Fuchs et de Launay, Gites minéraux, II, 205–206. Lacroix, Mineralogie de la France, II, 1896, 457-458; III, 1901, 16–17.

† Bergeat, Die Erzlagerstatten, III, S. 883–884.

‡ Beck nach v. Fucks, Die Antimonlagerstatten von Kostaïnik in Serbien; Ztschr. f. prakt. Geol., 1900, 33-36—Antula, Revue générale des gisements métallifères en Serbie, 1900, 70–73.

¶ Cox, Discovery of oxide of antimony in extensive lodes in Sonora, Mexico, Am. Jour. of Science, (3) XX, 1880, 42; Ref. Ztschr. f. Krist., V, 1881, 510; Halse, Note on the antimony deposit of El Altar, Sonora, Mexico; Transact. Fed. Inst. Min. Eng., VI, 1893–1894, 290–294.

are those at respectively West Gore*, Hants county, N.S., and at Prince William†, near Fredericton, N.B. Gold in varying amounts is always present in the ores of the former. Antimony minerals also occur at South Ham, Quebec, and in numerous localities in British Columbia. The greatest number and most valuable occurrences of antimony ores are found in France and Italy. Antimony is also found in other countries, and notably in China.

In exceptional cases, the ores of antimony, instead of being associated with gold, may be regarded as unusual developments of the rich silver veins. The Wheaton river occurrences are of this type, and are included under division (*c*). An example of a deposit of this type, designated by Freiesleben as the Mobendorf type, was worked until the "Sixties" at Mobendorf‡, in Saxony, seven miles north-west of Freiberg; while like deposits also occur east of Broken Hill in the Barrier Range of New South Wales*. In both of these localities, the ores occur in crystalline metamorphic rocks; while those on Carbon and Chieftain Hills, are found in granites and andesites and to a lesser extent in the clastics of the Chieftain Hill volcanics.

GENERAL.

The veins of antimony ore along the Wheaton river vary in width from a few inches to five feet, and consist principally of stibnite, sphalerite, tetrahedrite (grey copper), galena (silver bearing), and antimony ochre. The latter occurs near the surface as a product of oxidation. In certain places the veins are made up almost wholly of stibnite. The gangue material, when present, is usually quartz, although barite occasionally is substituted. Some veins are decidedly persistent, outcropping for a distance of over two thousand feet; but others are less regular and have, so far, been traced for short distances only. The veins usually strike in a direction a few degrees north of west, and dip to the north at angles varying from 40 degrees to nearly 90 degrees.

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* W. R. Askwith; West Gore Antimony deposits, Min. Soc. of N. S. 1901. D. F. Haley;—Eng. & Min. Jour. Vol. 88, No. 15, pp. 723–724.

† G. A. Young;–A descriptive Sketch of the Geology and Economic Minerals of Canada. Geol. Surv. Branch, Dept. of Mines, Canada.

‡ H. Müller; Erzlagerstatten bei Freiberg. Cotta's Gangstudien, I, 1850, p. 104.

Some veins consist chiefly of stibnite with only subordinate quartz, while others with parallel strikes and similar dips are mainly composed of quartz, argentiferous galena and grey copper. The silver seems to be, for the most part, at least, associated with the galena; so that those veins in which galena predominates are correspondingly richer in the precious metal.

The veins in the different formations appear to have had a common origin and to be of the same age. They all, as above mentioned, have similar dips, strikes and values, and do not appear to have been affected by the differing character of the rocks that they intersect. The antimony-rich, and silver-rich veins occur within a few feet of one another in granite on the Porter claim, and veins practically identical in composition to the vein containing the greatest amount of stibnite on this claim are found on Chieftain Hill and on the Empire claim on Carbon Hill, in andesites, and also near the top of Carbon Hill in clastics.

The andesites are the most recent rocks in which these ore deposits occur. The andesites cut the Cretaceous sediments and must be of late Cretaceous or Tertiary age. The veins are themselves cut by basalt and rhyolite dykes of late Tertiary age. This, then, fixes the age of the ores as belonging to the late Cretaceous or early Tertiary.

According to modern theories concerning the formation of ores, the deposits here considered were deposited by circulating waters containing dissolved gases and metalliferous compounds, and are probably genetically connected with the intrusion of igneous rock. The mineral constituents were deposited between the walls of fault fissures, that appear to be of slight displacement: and the walls themselves have been but little, if at all, replaced by the ore matter. The igneous rock to which the deposits owe their origin may probably be the andesites in which some of the veins are found. All the other known, more recent, igneous rocks of the district, cut the ores and so cannot have been instrumental in their formation. The ores were deposited in the andesites after the outer portions, at least, of these masses were cooled, as the ore-fissures cut this formation. So it would appear that while the inner portion of the andesitic magma was still hot, these antimony ores were being deposited beyond the influence of the heated interior, *i.e.*, outside its metamorphic aureole.

As regards the probable continuity of the deposits, it is now known that veins very rarely continue in depth for a distance greater than their length at the surface. Some of the Wheaton river veins outcrop for over 2,000 feet, while others apparently do not exceed forty or fifty feet in length. Further, the veins are only slightly oxidized and but little leaching has taken place. The oxidized zone, in the case of the veins richest in stibnite, can generally be measured in inches, and, in the more pronounced silver-bearing deposits, it extends downward apparently, a few feet only. The northern climate may have exerted an important influence in this matter, in that as the ground is frozen during the greater part of the entire year, conditions are unfavourable to chemical action. This would all indicate that no zone of marked secondary enrichment is likely to be encountered lower down at or near the water-level, particularly in the case of the stibnite veins. Moreover, the minerals, at the surface, are of those that have proven themselves, in other places to be of primary origin. The tetrahedrite (grey copper), although regarded by certain authorities as in some cases of secondary origin, is for the most part primary mineral. There is, therefore, no reason to suppose that the more persistent veins will rapidly decrease in value with depth. In fact, the surface evidence would indicate that the ores should continue for a considerable portion of their vertical extent without any very marked change in the amount of their valuable contents.

MINERAL CLAIMS.

The chief and most promising prospects as so far developed are included in the Porter group of three claims, the 'Porter,' the 'Empire,' and the 'Excelsior.' The only other claims on which work, other than the necessary "assessments," has been undertaken, are the 'Morning' and the 'Evening' claims on Chieftain Hill, and a claim situated about a mile to the north of the 'Porter.'

The Porter Group.—On the 'Empire' are the old workings of Corwin and Rickman who, it is presumed, here made their first discoveries. The ores occur in an andesite containing considerable iron. This formation, for several feet from the surface, is badly decomposed, so much so, as to almost completely disguise its nature. It presents a very bright reddish to yellowish appear-

ance and is much disintegrated in many places. At three or four spots, however, some quite large pieces of almost solid stibnite, varying from 6 inches to 10 inches in diameter, were found associated with more or less quartz and barite gangue. Outcrops of several veins of from apparently 6 inches to 2 feet wide, have been uncovered on this claim.

On the 'Porter' claim, the outcrops of six veins were noted. These are all in the Coast Range granitic rocks, and appear to strike about N. 77° W., and to dip from 40° to 50° to the northwest. The most likely appearing vein on this property varies from 14 inches to 3 feet in thickness, and has been traced for over 200 feet on the surface. Portions of the vein, 12 to 14 inches wide, were observed to be of almost pure stibnite. Five feet down the hillside is another vein varying from 6 to 12 inches thick, similar in character although not so highly mineralized. Again at distances of respectively 95 feet and 130 feet measured in a horizontal direction from the main vein, two other veins occur, the one 2 inches wide and the other 6 inches wide at the outcrop. In these last deposits the vein filling is quartz, galena, and grey copper.

An incline shaft about 10 feet deep has been sunk on the main vein, and in addition, a drift has been commenced which is intended to crosscut at least four of the veins. This crosscut is expected to top the main vein at a distance in of about 340 feet, and at a vertical depth below the surface of 180 feet, but, when visited by the writer in September last, had only been driven about 140 feet, and no oreh ad been encountered. It is reported, however, that some of these veins were crosscut during the past winter and that very encouraging values were shown by assay.

Assays of samples of surface ore of the better class, containing considerable galena and grey copper, often carry from 100 to 200 ounces of silver per ton, but Carbon and Chieftain Hill ores rarely contain more than traces of gold. The ores from selected spots in the main vein on the Porter claim have yielded from 70% to 65% antimony. One analysis of ore from this claim sholwed results of 50 ounces silver, 31% lead, and 18.75% antimony. This sample is representative of the class of ore containing both silver and antimony, in important quantities. The stibnite itself, seems, in many places, to be argentiferous.

Goddell's.—This claim is situated on the Wheaton river slope of Carbon Hill, to the north of the Porter claim and probably a mile distant from the latter. Two veins, not more than 20 or 30 feet apart outcrop in a gulch here, and can be traced for over 200 feet on the surface. They occur in granite, strike north 80° west and have an almost perpendicular attitude. They consist chiefly of quartz carrying some stibnite and arsenical iron, and are two and six feet thick, respectively.

The Morning and *The Evening* are the two main claims on Chieftain Hill. These are located on the same vein which, near where it crosses Chieftain Gulch, is 5 feet wide and consists chiefly of quartz and stibnite. A portion of this vein, 2 feet thick, is composed almost entirely of this antimony mineral, which exhibits beautiful columnar and radiated structures. Fifty feet from this place in both directions, the vein narrows to from 6 inches to 1 foot. This deposit is in a fissure in a fine-grained, greenish andesite, strikes north 85° west and has an almost perpendicular attitude.

PLATINUM MINING IN THE TULAMEEN DISTRICT, B.C.

By CHARLES CAMSELL, Ottawa, Ont.

(By permission of the Director of the Geological Survey).

The Tulameen river is a small stream that, rising on the eastern slope of the Cascade mountains in southern British Columbia and flowing in an easterly direction through a part of the Interior plateau, joins the Similkameen river at the town of Princeton. The territory drained by the Tulameen river is called the Tulameen district. The town of Tulameen, or Otter Flat, is situated at approximately the centre of the district, some 38 miles north of the International boundary line and about 30 miles east of the Fraser river at Yale. The tributaries of the Tulameen river, worthy of important consideration in connection with the mining of platinum, are Granite creek and its branches, Cedar and Slate creeks, entering from the south, and Bear and Eagle creeks from the north.

HISTORY.

British Columbia, whose resources, it was at first thought, were of little value, except to fur traders, became a mineral producing country after the discovery of placer gold on the Fraser river in 1858. The large influx of miners in this and the years immediately following led to discoveries elsewhere in the colony, and in 1860 gold was reported to have been found on the upper Similkameen river, at a point a short distance above the mouth of the Tulameen river. It is, however, probable that some bars on the Tulameen river were also worked at this time, for after the Granite creek excitement in 1885, old workings were found on the Tulameen river, about the mouth of Slate creek.

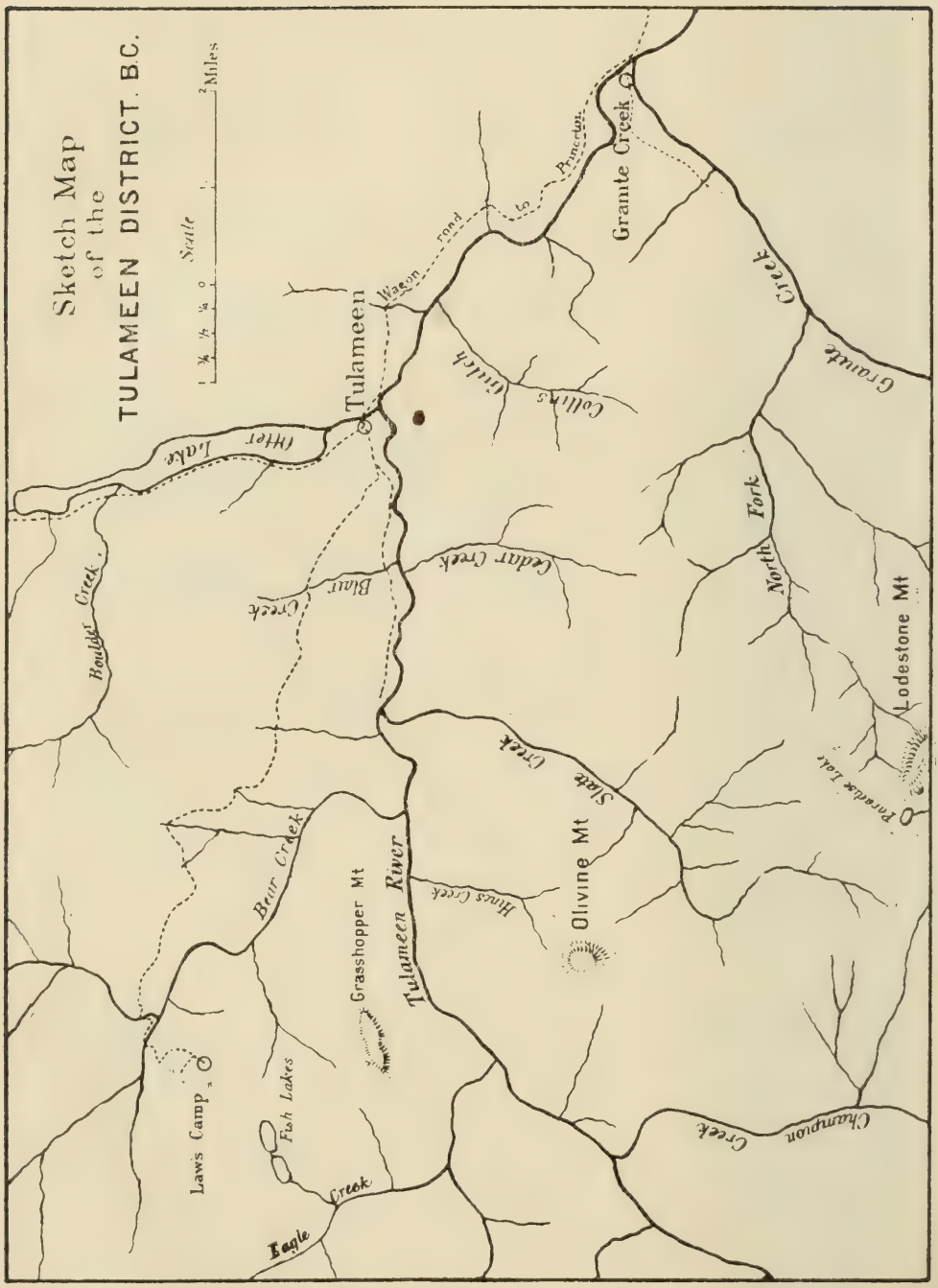
Sketch Map
of the
TULAMEEN DISTRICT. B.C.
Scale
Miles
Tulameen
Wagon Road to Princeton
Granite Creek
Granite Creek P.O.
Collins Gulch
Otter Lake
Boulder Creek
Blair Creek
Cedar Creek
North Fork
Granite
Lodestone Mt
Paradise Lake
Slate Creek
Olivine Mt
Bear Creek
Grasshopper Mt
Tulameen River
Hines Creek
Laws Camp
Fish Lakes
Eagle Creek
Champion Creek

FIG. 1.

Although it is now known that some of the bars worked by the pioneer miners contained platinum in association with the gold, no statement in respect of the recovery of the former metal was ever officially recorded in British Columbia. Dr. Dawson, however, mentions having received in 1877 a small sample, containing about an ounce of platinum, obtained from some workings on the Similkameen river, about three and a half miles above the town of Princeton.*

For the twenty-five years following the first discovery of gold on the Similkameen river, placer mining was not prosecuted with any great vigor, and in the latter part of this period was carried on almost exclusively by Chinese. The discovery of coarse gold on Granite creek in 1885, by a cowboy, one John Chance, revived the declining industry and occasioned the greatest "rush" in the mining history of the district. Other discoveries, higher up the Tulameen, quickly followed, and in the subsequent three years the output of the district reached its maximum. Since then, and until the present time, there has been a second gradual decline in output; but it is hoped that this may soon again give place to activity, not only in placer, but also in lode mining.

The history of platinum mining in the Tulameen dates from the Granite creek excitement of 1885, and, as platinum is essentially a product of the placers, its history is intimately bound up with that of gold placer mining here.

In the early days on Granite creek, when platinum was purchasable at the rate of about 50 cents an ounce, it was regarded by the miners as a detriment rather than otherwise, and usually was not even saved in the "clean-up." When a little later, however, the price had advanced to about $3.00 an ounce, the metal when recovered was saved, and this has been the practice since.

Not all of the creeks tributary to the Tulameen river contained platinum in association with the gold. In general it may be said that the placers on creeks on the southern side of the Tulameen river from Granite creek up to Champion creek, including the Tulameen itself, carried platinum as well as gold; while on the northern side of the river only Bear and Eagle creeks were productive, although not to a very large extent.

(*) Geol. Survey of Canada, Report of Progress, 1877-88, p. 156 B.

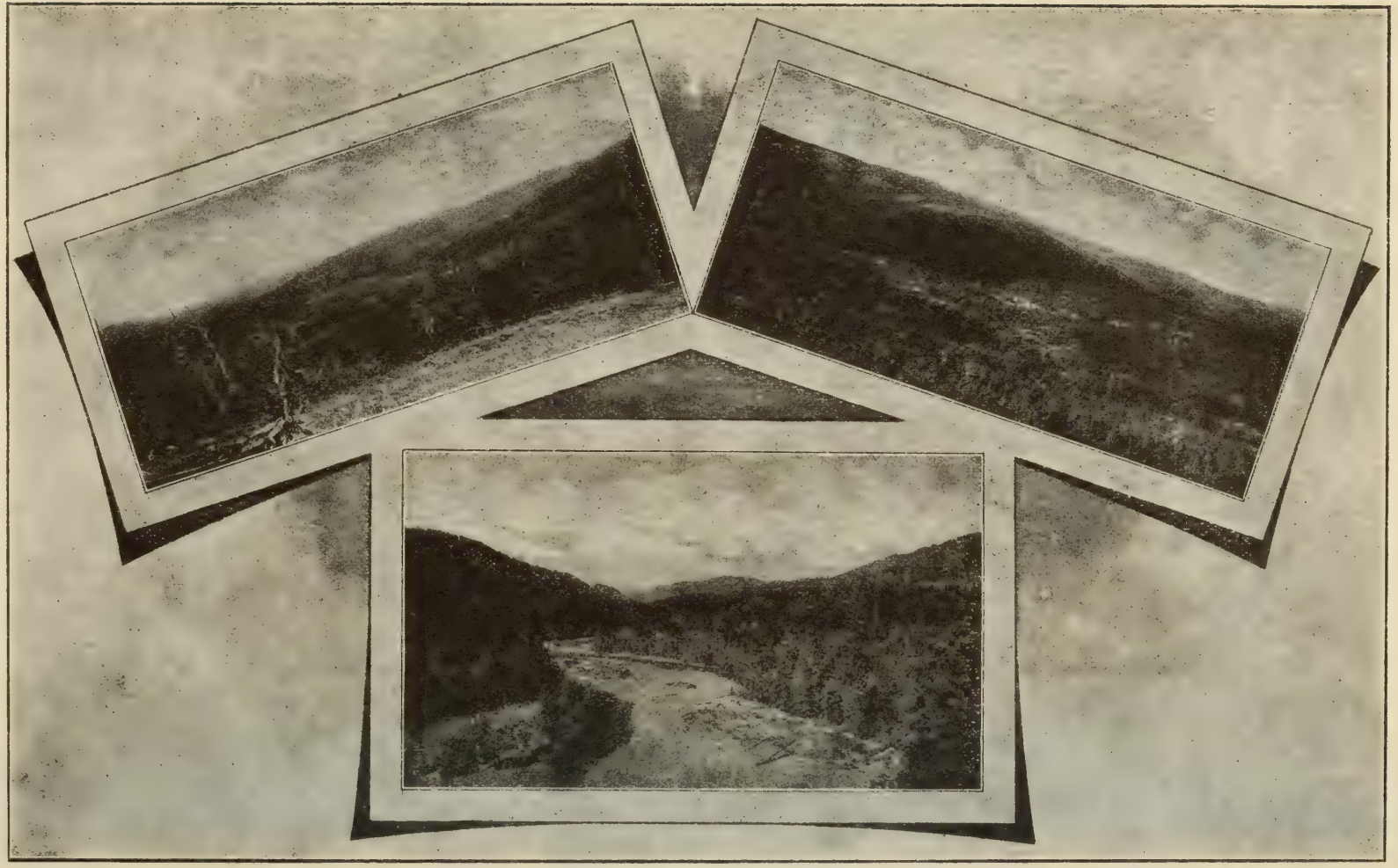

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Fig. 2.—Typical view of the interior

4

Fig. 4.—Valley of the Tulameen river,

3

Fig. 3.—General character of the

The best placers were undoubtedly those of the Tulameen river itself between the mouths of Slate and Champion creeks. Here the coarsest nuggets were found, and the proportion of gold to platinum was about one to one. Slate creek was next in importance, and then Cedar creek, Granite creek and its western tributaries, Bear and Eagle creeks. Boulder creek, flowing into Otter lake north of the Tulameen river, though much worked for gold, contained no platinum. On the Tulameen river itself no platinum was found above the mouth of Champion creek, and below Slate creek the grains became finer and the quantity gradually decreased.

METHODS AND PROGRESS OF MINING.

The methods employed in the mining of platinum were those commonly practiced by the individual miner when mining for placer gold.

Previous to 1891 the miners in the country were without capital, and either worked singly or in small groups on ground which might be developed without large capital outlay and which promised quick returns. The shallow bars and the beds of the streams naturally received first attention, and later the benches and some of the deeper gravels. By wing-damming, the beds of the streams were made accessible, while in the deeper workings drifting on the bed rock was the common method employed to reach the pay gravels. The pay gravels in Granite creek rested directly on the solid rock, and were in a hard layer compactly cemented together, but which disintegrated readily on washing. The washing operation was one either in a rocker or in a string of sluice boxes, by which means the platinum was concentrated with the gold in the black sands.

The earliest attempt at hydraulicing on Granite creek was that undertaken by R. Stevenson and W. E. Hogg in 1891. A flume four miles in length was installed on the west bank of Granite creek, and work started on claims lying about three-quarters of a mile above the mouth of the creek. The promoters of this company became involved in litigation with the owners of ground below them, and were forced into liquidation. The court, acting as receivers, secured, it is stated, from the sluice boxes about $900, principally gold.

Mr. Hogg afterwards worked a small pit four miles below the mouth of Granite creek, and washed the gravels from an old high channel of the Tulameen river. This venture was continued for in the season, but in the following spring the pit filled with wash from the mountain side and was never re-opened.

In 1892 the Tulameen Improvement Company began operations on a bench on the Tulameen river below the mouth of Eagle creek. A saw mill was imported, at a time when the only means of transport was pack horses, and placed at the mouth of Eagle creek. A flume was built to convey water from Eagle creek, and hydraulicing operations were carried on for two seasons under the directions of Judge Murphy. The proportion of

Fig. 5.—Village of Granite Creek, at the Junction of Granite Creek with the Tulameen River.

gold to platinum at this point was about one to two, and the recovery of platinum was high; but the available ground was limited and the results obtained did not pay for the cost of plant and management.

At the mouth of Slate creek, hydraulic operations were conducted for a short time by Alexander Swan, on a high bench above the Tulameen river. A flume about a mile in length

was laid up Slate creek and the water turned on to the bench. The bench was then found to consist largely of boulder clay, and the only payable portion of this was a bed of stream gravels approximately twenty feet thick, nearly half-way down the bench, between two deposits of boulder clay. The boulder clay was so stiff and compact that water had little effect on it, and the pay gravels were not easily reached. The undertaking was consequently not a success.

Within the last four or five years placer mining operations have been actively prosecuted by a few individuals only. Chinese have worked over the bed of the Tulameen river in the portions about the mouth of Slate creek and between the mouths of Eagle and Champion creeks. The heavier constituents of the gravels were recovered during the season of low water, by diverting the course of the water by wing-dams from the centre of the stream to either banks, thus leaving the centre of the stream free for working. Other miners have been simply extracting pay from cracks and from under large boulders as were left by the earlier operations.

A short distance above the mouth of the North Fork, on the main Granite creek, Messrs. R. A. Lambert and Stewart are doing the only serious placer mining in the whole district. The preliminary development has been carried on by five men for the past three seasons, but the actual sluicing of the gravels may only commence in the coming season. Lambert and Stewart have a lease of one-and-a-half mile of the creek bed above the North Fork, a very small part of which had been worked in former times. The gold recovered from these portions was very coarse, though the bed rock was only reached in one spot. In this particular portion, which was but 200 feet in length, the yield is said to have been $1,200.00 to the length of a sluice box, where the gravels in the stream bed had a width of 40 of 50 feet. This yield included nuggets, the gold value of which was from $100 to $150; the platinum, however, was fine. The remainder of the creek bed covered by the lease is deep ground and could not be bottomed. Lambert and Stewart are now engaged in cutting down the bed of the stream in the lower part of their lease, in order to reach bedrock and recover the gold and platinum lying on it. Commencing at the lower end of their ground, a dam has been

constructed across the stream bed, while 600 feet of a board flume carries the water over the portion of the channel which it is proposed to first work. The large boulders and rock in the lower part were blasted away, thus enabling the removal by ground-sluicing of a depth of about 25 feet of gravel, which before formed the bed of the stream. The depth of gravel overlying the bedrock is now but five feet, and the point has been reached when the gravels can be shovelled into the sluice boxes. This, however, can only be done after the season of high water has passed. The returns should show a proportion of about four parts of gold to one of platinum, and should amply repay the cost of the preparatory work.

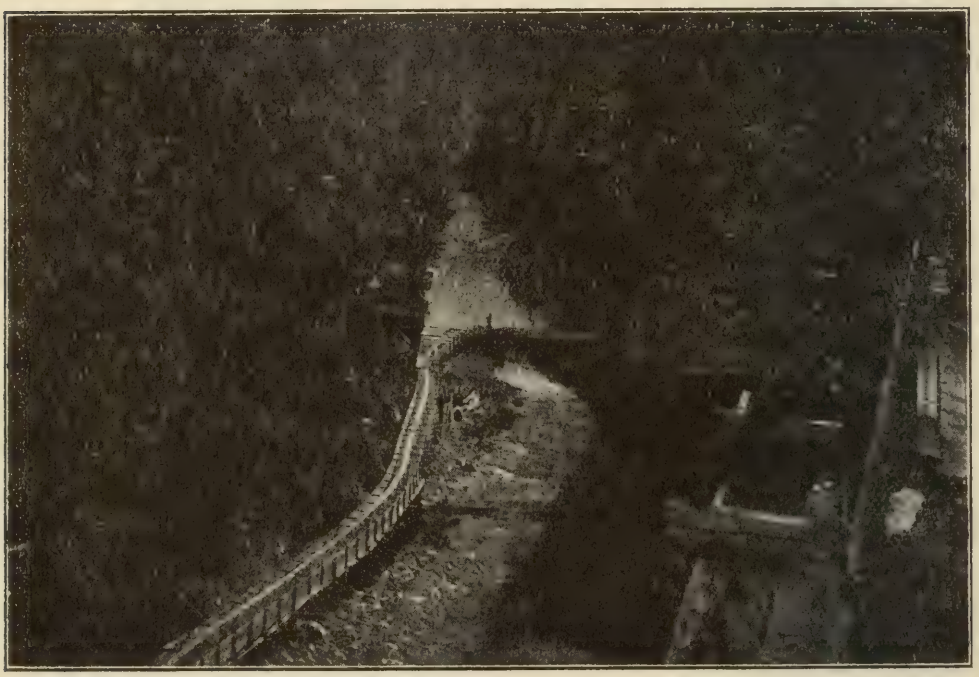

Fig. 6.—Lambert & Stewart's placer mining operations on Granite Creek.

A company recently organized in Vancouver, the British Columbia Platinum Company, has obtained from the British Columbia Government three leases in what was formerly the most productive platinum district. One of these leases applies to an area on Slate creek, and the others to areas on the Tulameen river above Slate creek. The Company proposes to first prospect the ground with a Keystone drill, and then mine it by ground sluicing or by drifting on the bedrock.

ORIGIN AND FORMATION OF THE PLACERS.

Much of the gold and platinum found in the Tulameen district is coarse, and has that rough unworn surface characteristic of nuggets which have not travelled far from their original source, Even in the beds of rapid streams the distance to which coarse gold travels is as a rule not considerable, and the same rule applies to platinum, which has a specific gravity not greatly different from that of gold. Much of the gold of the district is still found imbedded in quartz, while the platinum is often associated with pyroxene, olivine or chromite. It is to be concluded, therefore, that the present placers are not very old; that they have been derived from the breaking down of rocks not very far distant, and are not the result of the working over of more ancient placer deposits formed by earlier streams.

A possible source for some of the gold and platinum of the district is certain old beds of sandstone and conglomerate, which have been determined as Oligocene in age and which outcrop on Collins gulch, Blair creek and the northern face of Jackson mountain. In the Kamloops district to the north, Dawson cites three localities in which he found Oligocene conglomerates containing traces of gold*; hence, on this evidence, there is no reason why both gold and platinum should not be found in the Oligocene conglomerates of the Tulameen. It is not known, however, whether any tests have ever been made of these beds. At the same time, because these conglomerates are some of the youngest rocks in the district, they have been undoubtedly derived from the same rocks which have formed the present stream deposits; and because these stream deposits are productive in both gold and platinum, it is to be expected that the Oligocene conglomerates will also carry a certain quantity of these metals. Whether that quantity shall have been sufficiently concentrated to form payable deposits is not known, but a test to ascertain this point might well be worth while.

The ultimate source of the platinum, either in the older or the younger placers must of necessity have been the solid rocks which underlie and are adjacent to them. The constituents of placers have been produced by long processes of erosion, and the

(*) Geol. Survey of Canada, vol. VII, p. 314 B.

concentration of the metals therein is the result of the transportation and working over of the constituents by the streams. As placers are usually thin and unconsolidated deposits, and are easily removed by erosive action, only the most recent usually now remain, and these are found in the beds of the present streams.

The shape and size of the mineral in the placers are important factors in the process of concentration. The finer the mineral the more easily it is transported, so that the larger nuggets are found near the original source. The shape of the nuggets is also an indication of the distance they have travelled; thus, angular and unworn nuggets imply the proximity of the original source.

It was ascertained by the miners that no platinum was contained in the gravels of the Tulameen river above the mouth of Champion creek; but thence to the mouth of Slate creek and in Slate creek itself were found the richest diggings. As the distance increased downstream from Slate creek the platinum gradually decreased in quantity, the grains became finer and had a much more water-worn appearance. The platinum bearing tributaries of the Tulameen river besides Slate creek, were Cedar, Eagle and Bear creeks, with Granite creek and its western branches. These latter, however, contained a diminished quantity of platinum, while too the grain of the metal was finer. All these streams, with the exception of Cedar creek, have their origin in or else cut through a belt of very basic rocks, which runs from the head of Newton creek at Lodestone mountain northward across the Tulameen river to the first west branch of Bear creek. This belt of basic rocks is peridotite, having a flanking border of pyroxenite. From a careful study of the geology of the platinum made in 1901, Prof. J. F. Kemp (*) concluded that the original source of the platinum was in both the peridotite and the pyroxenite, and that the placers were derived from these by the ordinary processes of decomposition, erosion and stream concentration. His conclusions were based both on the distribution of the placers, and on the occurrence of olivine, chromite and pyroxene—all constituents of either the peridotite or pyroxenite—with the platinum in the nuggets. From knowledge, moreover, of the relation of platinum to rocks

(*) Bull. U. S. Geol. Survey, No. 193, p. 38.

of this character in other parts of the world, no other source than that ascribed would seem possible. Prof. Kemp's findings in this respect were corroborated by the writer in a geological survey of the district in 1909. The fact that Cedar creek, while carrying platinum, does not cut either peridotite or pyroxenite does not invalidate the conclusion as to source, for the platinum here might have been derived from Tulameen river gravels washed thither at an earlier period; or again its derivation might have been the Oligocene conglomerates through which it flows.

The age of the intrusion of the peridotite and the pyroxenite is probably later Mesozoic, from which time erosion has been almost continuously proceeding until the present. It may be premised, therefore, that placers were forming throughout that erosion period; and this would be accompanied by the concentration of the platinum on the heavier constituents. The only placers that now remain are those of Oligocene, pre-glacial and inter-glacial age; and the present stream deposits. The Oligocene placers have not been tested; but the others have been mined more or less for gold and platinum. Thus pre-glacial deposits, deeply buried by glacial drift have been mined; and at the mouth of Slate creek inter-glacial stream deposits are found lying between beds of boulder clay. The most productive gravels, however, are the recent stream deposits, and from these the major proportion of the gold and platinum yield of the district has been won.

Character and Composition of the Platinum.

Platinum rarely occurs in large nuggets and never in nuggets comparable in size with those recorded in the case of gold. The largest nugget ever found is reported to have come from the Ural mountains in Russia, and weighed 21 pounds troy or 252 ounces. In the Tulameen district the nuggets are invariably small, and the writer has not heard of nuggets from this area whose weight exceeded half an ounce, although he has seen one which approximated that weight.

Again the platinum of the Tulameen district is in small grains or pellets, varying in size from one to four millimetres in diameter; the weight of each grain is measured in milligrams. The grains are generally rounded in shape and not flattened or angular like the gold that occurs with them. The surface is usually pitted

with rounded cavities, and these cavities are often filled with foreign rock matter. In the majority of the platinum grains examined this foreign matter proved to be chromite, but Prof. Kemp states that he also found both olivine and pyroxene associated with the platinum (*).

All the platinum can be separated into two parts, namely, magnetic and non-magnetic. The non-magnetic part forms the greater proportion of the total bulk. The magnetic part was found to consist of grains which attracted the magnet. These grains are loosely covered with small particles of a black metallic mineral, probably magnetite.

The heavy minerals associated with the platinum in the concentrates were found to be magnetite, chromite, and native copper; and Dawson also reports finding some silver glance in certain concentrates (†).

The only analysis made, so far as known, of the platinum of the Tulameen river was that by G. C. Hoffman of the Geological Survey in 1886 (‡). After separating the associated grains of foreign matter, this sample was found to consist of the following minerals:..

Platinum	72.07 per cent
Palladium	0.19
Rhodium	2.57
Iridium	1.14
Osmium	
Copper	3.39
Iron	8.59
Osmiridium	10.51
Gangue	1.69
	100.15

Formerly producers of platinum in the Tulameen district were paid only for the platinum per cent of the product. In 1907, however, a distinction was made for the first time between ordinary and hard platinum. The hard platinum is rich in iridium and osmium, and commands a somewhat higher price. In

(*) Bull. U. S. Geol. Survey, No. 193.
(†) Geol. Survey of Canada, Vol. 3, p. 62 A.
(‡) Geol. Survey of Canada, Vol. 2, page 5 T.

December 1909 quotations on the New York market for the two varieties of the refined product were $29.50 for ordinary platinum, and $33.25 for the hard metal.(*) Later reports show a marked and steady increase in the price paid for the hard metal. The Tulameen platinum is classed by the dealers as hard metal and consequently realizes the higher price. Payment is now made for both the platinum and the osmiridium content.

PRODUCTION.

Figures bearing on the total production of platinum from the Tulameen district are incomplete and details are difficult to obtain. The reports of the Minister of Mines for British Columbia contain statistics of the value of the platinum produced from the years 1887 up to 1905, but prior and subsequent to these dates no data are given. It is known that during the first two years of mining in the Tulameen, after the discovery of Granite creek, much platinum was saved together with the gold, yet no record of the yield is given. Again although the statistics for the years following 1905 contain no mention of platinum, the writer has since seen platinum, to the amount of about 100 ounces, in the possession of Chinamen working on the Tulameen river.

Much of the placer mining done in the Tulameen district has been undertaken by Chinese, and only those who have tried to secure information from these miners realize how difficult it is to thus obtain reliable data. Necessarily, therefore, the statistics of production here given are incomplete; and doubtless err very considerably on the side of underestimation of output.

Some compilers in order to make proper allowance for the production for which Chinese miners are responsible, actually go so far as to double the returns as published in the government reports. Thus Mr. C. F. Law, who has had a wide mining experience in the Tulameen country, and in recent years has purchased practically all the platinum produced in this district, estimates the total output at about 20,000 ounces, having obtained vouchers from platinum purchasers, accounting for over the half of this estimated yield, while the balance is attributed to the production of Chinese miners.

(*) Eng. and Min. Journal.

The following returns, from the reports of the Minister of Mines for British Columbia, represent the value of the platinum produced for the years 1887 to 1905 inclusive. For the figures presented in the third column, however, representing yield in ounces, the writer is mainly responsible, having arrived at the results by calculation, based on the average prices paid for the metal in the respective years:—(*)

Year.	Value.	Ounces.
1887	$ 5,600	1,400 to 2,000
1888	6,000	1,500
1889	3,500	1,000
1890	4,500	1,100
1891	10,000	2,000
1892	3,500	500
1893	1,800	257
1894	950	160
1895	3,800	633
1896	750	125
1897	1,600	266
1898	1,500	100
1899	825	137
1900	....	....
1901	457	22
1902	190	10
1903	....	....
1904	420	20
1905	500	30
	$45,892	9,860

METALLURGY.

The early method of separating the platinum from associated minerals in concentrates were crude in the extreme. The platinum of the placers was a secondary consideration compared to gold, for the primary object of all the miners in the district was the recovery of the gold.

(*) Mineral Resources of the U. S., 1906, page 551.

Platinum does not amalgamate with pure mercury. In the first year of mining, therefore, when the miner came to clean up his concentrates, he proceeded to separate his gold by amalgamating it with mercury, and valuable constituents which would not amalgamate were disregarded. In the second year, when the commercial value of the platinum began to be realized, the concentrates that would not amalgamate with mercury were washed in a gold pan and the platinum separated by this method. Naturally this platinum was not very pure, frequently much chromite or magnetite being also present. This, however, was invariably taken into account by local dealers, who made a price, affording a margin to protect themselves from any loss by reason of impurities.

As no systematic operations for the recovery of platinum primarily, have yet been undertaken, the methods of separation have not improved. So far as at present known the mineral does not occur in commercial quantities in any other association than in the placers. Though a few prospectors have in recent years been engaged in a search for platinum *in situ*, no success has as yet been attained in this direction, and it is extremely doubtful if it ever will be. The placers, therefore, are the only available source. From these the platinum must necessarily be recovered by the usual methods employed in the placer mining of gold.

In reference to the separation of platinum from gold and other heavy minerals concentrated in the washings, an allusion to certain experiments carried out by Dr. D. T. Day and Prof. R. H. Richards, at Portland in 1905, on the black sands of the Pacific coast, may be of service. In these experiments it was found that platinum and the platinum metals had a curious relation to mercury (*), for, to quote from the published account of the investigations: "So long as the sodium amalgam is rich in sodium they amalgamate perfectly, but as soon as the sodium is spent the platinum metals leave the amalgam and refuse to remain combined with it. This property will prove of value in cleaning platinum metals, for they can at first be separated from the sand with the gold, and then by simply standing in water, the gold and platinum amalgam part into gold amalgam and free platinum grains which can easily be separated in the pan. The indications are that this

(*) Min. Res. of U. S., 1905, page 1236.

property may be used for commercial separation as well as for assay, if the sodium does not make the expense too high. The clean up barrel or barrel amalgamator.....may prove suitable for the treatment on a commercial scale wilth sodium amalgam."

There are, no doubt, placers in the Tuameen district that would well repay a reasonable capital outlay in an endeavour to recover platinum therefrom; more especially so, in view of the present high market value of the metal; but here, as elsewhere, successful results cannot be expected without the exercise of intelligence and competency in the direction of operations.

THE PROBABLE NUMBER OF PRODUCTIVE VEINS IN THE COBALT DISTRICT.

By G. R. Mickle, Toronto, Ont.

(Cobalt Branch Meeting, July, 1909).

To anyone who has had the opportunity of seeing the great number of veins, within a small area, existing in the Cobalt district—veins rich, poor, and absolutely barren—the desire to form some estimate of the probable number of productive veins that will be ultimately found, and to ascertain how the district compares with others, is natural; and has resulted in the following calculation.

One of the first things that must strike the observer, whose attention is not confined solely to veins capable of being worked at a profit, is the extraordinary number of veins, most of them economically valueless, to be found here, but still having, in the writer's opinion, a bearing on the study of the camp. In short the calcite vein has not been properly appreciated, although Dr. Drummond wrote a poem in its honour.

The tract containing all the known undoubtedly productive veins, extending from near the boundary between the townships of Coleman and Lorrain westwards about three miles, and from the north boundary of Coleman township south, a distance of over three miles, embraces an area of nearly ten square miles. Within this area there are, it is probable, over 2,000 veins. This estimate is based on observations in a number of cases where, during the seasons of 1905 and 1906, claims were thrown open for lack of discovery, and the size of a claim reduced from forty to twenty acres. In a number of instances, for various reasons, generally because of the vicinity of some good discovery, most intense energy was thrown into exploring certain of these twenty-acre

parcels, and the result was that almost invariably five to seven veins would be found on the twenty acres, or ten to fourteen on the forty acres; and, as there are sixteen forty-acre claims in a square mile, there would be 160 claims (forty acres) in the ten square miles, and therefore, 1,600 to 2,240 veins altogether in this area; the probability being that the larger number is more nearly correct, as the observations were not taken in the parts most productive in veins, and no doubt some of the veins existing were not found.

Beyond this productive area of about ten square miles, the calcite veins are found in an unbroken stretch from Lake Temiskaming to the Montreal river, a distance of about fourteen miles; and at least eight miles in the north and south directions, or over 100 square miles. The number of veins, it is true, are not so great in these outlying parts, but in all probability there are not less than 15,000 veins, approximately, altogether.

In respect of the composition of these veins, excepting the calcite, and frequently small quantities of the metallic sulphides, (chalcopyrite, galena, zincblende, etc.), there is no metallic mineral. The closest scrutiny in a number of openings will fail to disclose the slightest indication of any characteristic minerals (such as smaltite, niccolite, etc.), associated with the silver in this district, not even cobalt bloom, although it forms very readily, and a very little smaltite will produce a great deal of bloom. Silver will be either entirely absent, or in mere fractions of an ounce per ton. A sample containing 0.3 of an ounce per ton would have only $\frac{1}{1000}$ of one per cent. silver; whereas any productive vein will give a considerable proportion of its material with 10 per cent. or more of metal, counting cobalt, nickel and silver together, or at the very least ten thousand times as much metal as the one carrying only .3 ounce per ton or less. No theory of concentration can account for any such difference as this, and the only conclusion one can arrive is that the barren vein and the productive vein did not originate from the same source.

The barren vein, as mentioned above, is found over an area of more than 100 square miles, and includes probably 90 per cent. or more of the total number of veins. Between the barren and the productive veins are found those containing trifling silver contents, say, over .001 per cent., or .3 ounce per ton, and cobalt contents varying from small showings of bloom to cobalt ore. These

are found over a much wider area than the productive silver veins, so that we have a vast number of barren veins spread over a wide area; a smaller number, perhaps 5 to 10 per cent. of the whole, confined to a smaller area, which contain more or less cobalt but no workable quantities of silver; and finally the productive silver vein, probably less than 1 per cent. of the total number, and found over less than 10 per cent. of the area. This naturally suggests three successive periods or operations to form one of the productive veins, and agrees with theories already propounded. (See Report Bureau of Mines.)

Referring back to the productive area of about ten square miles, we find this is covered by three distinctive formations, namely, Huronian, Keewatin and diabase. If the water and drift-covered areas, shown on the geological contour map by Dr. Miller and C. W. Knight, are distributed among these three formations where they probably belong (this can be done now without making any serious error), and if the areas covered by these different formations are measured by a planimeter it will be found that the distribution is as follows:—

Huronian	2.31	square	miles.
Diabase	4.85	"	"
Keewatin	2.25	"	"
Total	9.41	"	"

This is the area of the smallest rectangle that will contain all the known undoubted productive veins, using meridional lines as boundaries. If the rectangle is not enclosed by meridional lines, but by side lines running north-westerly and south-easterly parallel to the flow of the water in Cross lake, then the area will remain about the same, and about .8 of a square mile will be cut off the diabase east of Cross lake; and an equal extent west of the town of Cobalt, round Sassiganaga lake, added to the Keewatin, or the amounts would show, the Huronian remaining practically unaltered:—

Huronian	2.31±	square	miles.
Diabase	4.00±	"	"
Keewatin	3.10±	"	"
Total	9.40±	"	"

As will be seen, the manner in which the lines are run makes no appreciable difference in the calculation.

During the summer of 1907 the writer tried to form some estimate of the probable number of productive veins that exist in the district by noting:—

(1) What proportion of the total area within the productive zone appeared to be completely explored for veins.

(2) How many productive veins had already been found.

(3) How these productive veins were distributed among the different rocks mentioned.

As pointed out by Dr. Miller in the first report and map issued by the Bureau of Mines in 1905, the Huronian is much the most likely rock in which to find the valuable veins. A special effort was, therefore, made to note closely how much of the Huronian had been explored on each claim. By enquiries of the managers of the respective properties, from personal observation, and by making some allowance for the superficial scouring or light prospecting which has been done probably over every foot of ground in the most promising area, data was secured on which to estimate the extent of the explored area. All rock exposed has been seen, and every indication that did not involve heavy work has been followed up; and, in addition to this, there has been more or less desultory prospecting on nearly all of the properties. It has been assumed that all searching of this nature will find one-quarter of existing veins, so that on any individual property a certain number of acres, perhaps five or ten in a forty-acre claim, might be considered as thoroughly explored; then one-quarter of the balance was reckoned as prospected by the irregular means just mentioned. Computing by this method gave a total of 740 acres of Huronian still to be explored; the total amount of this rock being 2.31 square miles, or 1,478 acres; therefore 738 acres had been prospected, or exactly one-half the area.

In counting the number of productive veins, some arbitrary standard required to be fixed as to what should constitute a vein of this kind; and, as it was intended to make a comparison later on with similar districts in Europe, a standard was taken which would probably agree with their classification. For reasons that will presently appear, a vein that either already had, or appeared certainly capable of producing ore that would yield a

profit of, say, not less than $20,000, was classed as productive. The same vein found on two different properties was, of course, only once counted; and if the vein carried values in two different formations, it was credited to the one that apparently contained the most value. On this basis, at the close of July, 1907, there appeared to be in all sixty-six different productive veins. Of these, the Huronian was responsible for fifty-three, the Keewatin for six, and the diabase for seven. Assuming that these two last formations had been at least as much prospected as the Huronian —and they were probably more prospected, as most of the conglomerate area was taken up and patented by the first companies, and never subjected to the energetic prospecting for discovery— the chance of finding a valuable vein in a given area of the Huronian to the chance of finding one in an equal area of Keewatin, is, if the boundary lines of the enclosing rectangle are due north, south, east, west:—

$$\frac{53}{2.31} : \frac{6}{2.25}, \text{ or 9 to 1, approximately.}$$

Similarly, the $\times$ value of the Huronian as a locale in which to find veins is to the diabase:—

$$\frac{53}{2.31} : \frac{7}{4.85}, \text{ or 16 to 1, approximately.}$$

If the boundary lines of the enclosing rectangle are, as explained, parallel to Cross lake, then the chance of the Huronian to the Keewatin is:—

$$\frac{53}{2.31} : \frac{6}{3.1}, \text{ or 12 to 1, approximately;}$$

and the chance of the Huronian to diabase:—

$$\frac{53}{2.31} : \frac{7}{4.0}, \text{ or 13 to 1, approximately.}$$

Now, in order to compare the Cobalt area with similar areas in Europe, where there was no marked difference in the rocks in which the veins were found, as to probability of being the seat of veins, it will be necessary to reduce both Keewatin and diabase

to equivalent areas of Huronian. On the first basis, 4.85 square miles diabase $= \frac{4.85}{16}$ square miles Huronian, or .33 square mile.

If we assume throughout that one-half the area of both Keewatin and diabase was prospected, then there remain:—

.1.56 square mile to be explored ..... 105 acres

And 2.25 square miles Keewatin

$$= \frac{2.25}{9} \text{ Huronian} = .247 \text{ square miles,}$$

and one-half of this = .12 to be explored ..... 76 acres

181 acres

Or, on second basis:—

Diabase, 4.0 square miles $= \frac{4.0}{13}$ Huronian = .30 square miles.

and one-half of this equals.. .15 square mile ..... 96 acres

Keewatin, 3.1 sq. miles $= \frac{3.1}{12}$ Huronian = .26 sq. mile;

one-half of this = .13 square mile ..... 83 acres

Total equivalent area Huronian ..... 179 acres

Taking this at 180 acres, and adding Huronian, 740 acres, gives 920 acres as total area of Huronian, or its equivalent, unexplored; or, in square miles, 2.90, approximately, explored and and unexplored, and this should produce sixty-six more veins altogether, or 132 in all. The Huronian area by actual observation appearing to be one-half prospected and the Keewatin and diabase being assumed to be equally prospected, it was impossible to investigate the two latter areas with the same minuteness, and in any case it does not materially affect the calculation.

It may be considered that the superficial prospecting and spasmodic work indicated above is not equivalent to the thorough prospecting of one-quarter of the area. Undoubtedly some allowance must be made on this account. It is known,

however, that all the earliest discoveries were made by means of superficial work; but, on the other hand, it will, of course, be evident that such irregular prospecting, as opposed to systematic trenching and underground work, will certainly not result in the discovery of even one-half existing veins. The truth, therefore, lies somewhere between these two extremes, and the most rational plan seems to be to take the mean or one quarter. The probable difference between that and the actual truth must be small. Assuming for the moment that the superficial prospecting, etc., is worthless so far as the Huronian area is concerned, then so much more remains to be prospected, and, carrying out the calculation in the same way would make a difference of about 28 more veins, or a total of 160, still assuming that half of the existing veins in the Keewatin and diabase have been found. Each difference, therefore, of one per cent. from one-quarter, or twenty-five per cent., will make a difference of about one vein plus or minus.

Let us compare, in respect of the number of veins, the Cobalt district with the most productive silver districts in Europe, viz., Annaberg and Schneeberg. In order to do this intelligently it will be necessary to understand the geological features, and also the industrial conditions under which mining operations in these European areas were carried on. Details of the mineralogical features of these European silver-cobalt veins are given in the report on the "Cobalt-Nickel Arsenides and Silver," already referred to. The accompanying map of Annaberg is reproduced direct by a pantograph from the one attached to a monograph by Hermann Müller (Die Erzgänge des Annaberger Bergrevieres), and the information given here is also mainly taken from the same source.

Briefly stated, the history of Annaberg was that after the first discovery in 1492, other followed rapidly; in 1496 there were six mines paying dividends. The prosperous period lasted nearly fifty years, and the whole life of the district as a silver producer about one hundred years. It must be remembered, however, that no mechanical power was employed and no powder (although long in use for warfare) was utilized on mining operations here; and the rate of progress was probably only one-fifth, or even less, as rapid as it would be now. As a compensatory factor

wages were low, and the value of silver was very nearly three times as great as it is now, viz., $1.46 per ounce.

A word as to the mode of operation will be in place. After a few successful ventures a feverish mining speculation seized all classes of the community—towns people and country people alike tried their luck. As soon as a vein was discovered the exclusive right to work it could be obtained by payment of a small fee from the mining office. It was the universal custom to divide the "mine" into 125 equal shares, to which were added four "free" shares, one of which was given to the owner of the ground on which the discovery was made (which is all he should be entitled to receive), another each to the town, the hospital and the Church. The silver produced from the rich ores was quickly converted into money at the mint, and the many fortunate enterprises attracted outside capitalists. The number of men employed as miners was about two thousand.

The rock was soft, but very soon, as depth was attained, water began to create difficulties, and as there were no efficient pumps or means of ventilation, the work by shafts had to be abandoned. Fortunately, from the configuration of the ground, long adits could be driven from the valleys to tap the veins. One system alone of these adits had a total length of sixteen miles. The maximum depth attained by any adit was about 700 feet.

The term "mine" was as indefinite then as it is now, and, as it will appear, the mines were mostly small affairs; thus the records showthat there were during the whole life of the district 635 mines that gave dividends; of these, however, over half, or 338, only lasted a year at most. The greatest number of profit-earning mines in any one year was 38, and the total number that produced silver was 969.

The richest mine in the Annaberg district paid dividends in its best period at the rate of $220,000 per year. Sixteen of the leading mines are credited with a total dividend of about $1,850,000 and the whole sum paid in dividends amounted to about $5,550,000 as far as recorded.

From the information given the total silver production can only be very vaguely estimated. Cases are mentioned where dividends per ounce produced amounted to over one dollar, and about fifty cents per ounce profit is mentioned as the average of

a number. It must be kept in mind also that it was the custom to divide whatever profit was made at once, so that, as soon as there was no profit, work had to be abandoned.

Including good and bad, an average of twenty cents per ounce profit produced would give only about 28,000,000 ounces as the total production, and 50,000,000 would certainly be an extreme estimate.

With regard to Schneeberg, which had a greater reputation, and was always spoken of as the greatest silver mining district in Germany, if there is any reliable information as to the production, the writer has not been able to find it. If we assume this to have been 100,000,000, and it was more likely nearer 50,000,000 ounces, it would still be smaller than the probable total output of the Cobalt camp, which should not be less than 200,000,000 ounces, which would thus greatly exceed in actual amount of silver that of those older districts, although, of course, in value the difference may not be so marked.

The Annaberg district proper embraced about twenty-one square miles. Included generally with it were several outliers of small area. The total number of known veins was 215, and of these 152 were in the Annaberg area proper, but, as the records of more than 300 old mines were lost, it is certain that a number of veins are not included in the count. On the same ratio, as about 970 mines show 215 veins, 1,270 would show 290 veins, and of those about 200 would be in the Annaberg area proper of twenty-one square miles. This is equal to 336 claims of forty acres, or about .6 of a vein per claim. As we have seen, the Cobalt area of 2.90 square miles, or forty-six claims, has already disclosed sixty-six veins, or nearly 1.5 veins per forty acres, and has already far surpassed the Annaberg district in number of veins per unit of area.

Looking at the map of the Annaberg district, an area of about eight square miles is shown having probably about 100 veins, this being the best part (only the cobalt-nickel silver veins are shown). It will be noticed that in many places the veins are grouped together, and in the corner of the map a forty-acre claim is drawn. This could easily be placed on certain portions of the map to include five to ten veins, and also in many cases there would be blanks. Practically the whole area is taken up with one kind of

rock—a biotite gneiss—the different dykes being so narrow that their area may be neglected. In a number of places kersantite dykes follow the veins. This can also be seen at Cobalt, most easily at the large cobalt vein (No. 8) on R. L. 404, near Peterson lake.

Referring to the Schneeberg district, according to Stelzner (Erzlagerstätten II., I.S., 738), 150 veins were found in an area of about ten square kilometres, or 3.8 square miles, or sixty-one claims of forty acres, or about 2.5 veins per claim. As on the Annaberg map, not all the veins are shown. About the centre the veins were massed very thickly, and it is here that the St. George mine was situated, which produced a larger nugget than any yet found in Cobalt. Notice the granite showing in the north-east corner. This was younger than the mica schist and clay slate in which the veins are found. The German geologists attribute the mineralization of the veins to the influence of the granite. A glance at the map shows that the slate and schist were equally favourable for the finding of veins.

If the Cobalt area were equally productive in veins with the Schneeberg, then the number would be:—

$$\frac{2.9 \times 150}{3.8} = 114, \text{ approximately.}$$

This is a difference of only about 14 per cent. in the number of veins in an equal area, considering the Huronian rock only. The estimate of the number in the Cobalt district cannot be expected to be closer than 10 to 20 per cent. ± of the actual truth. In the number of veins per unit of area, therefore, there is a striking resemblance between Schneeberg and Cobalt. It is not only in this respect that the similarity is seen; the way in which the veins occur in groups or clusters is also remarkakle. Just as values are concentrated in the veins in places, so the veins are concentrated in the country rock in certain spots, the degree to which this occurs being apparently about the same in the two districts. Thus about six productive veins on ten acres seems to be the maximum in both places; probably not over twelve or thirteen different veins fulfilling the conditions, as above mentioned, exist on any 40 acre claim. If the average number of veins for 40 acres is about three, and some have six or more, it follows that

others must have none. How many there are of this kind at Schneeberg can be seen by subdividing the whole area into 40 acre claims by drawing lines one inch apart. This will give 63 claims, and of these eleven have no vein at all and, therefore, were certainly worthless; and five more have such a short length of vein that they were probably worthless, or sixteen out of sixty-three or say one in four were valueless; three in four, therefore, were sure of success. It should be mentioned that about thirty of the veins are not shown on the plan of Schneeberg, this being a modern map produced from information gained in the period 1852 to 1893, when a determined effort was made to open up the mines at lower levels, in the hope that with modern appliances ore would be found which formerly could not be reached. This hope proved elusive; the old miners had taken out the best, and the results on the whole were disappointing. This plan shows everything projected on the plane of the lowest level. Veins not found on this level or which they did not try to find are missing therefore. If these thirty veins were distributed proportionately, it would reduce the number of the worthless claims by one-fifth, or make the chance of success about four in five. The length of the veins is, of course, a factor in this calculation, and it will be noticed that on the whole they are longer than in Cobalt, which would reduce the chance of success in the latter district somewhat.

Up to the beginning of July, 1909, the number of productive veins appeared to have increased to eighty-four. It is difficult, however, to count within five or six of the correct number, as subsequent working proves sometimes that, what appeared to be two separate veins, is really one, and *vice versa*.

THE CLAY AND SHALE DEPOSITS OF NOVA SCOTIA AND PORTIONS OF NEW BRUNSWICK.*

By HEINRICH RIES, Cornell University, Ithaca, N.Y.

(Annual Meeting, Toronto, 1910.)

During the summer of 1909 the writer, assisted by Mr. Joseph Keele, was engaged in a study of the clay and shale deposits of Nova Scotia and portions of New Brunswick, and the paper herewith presented gives in somewhat condensed form the main results of both the field and laboratory work. The detailed report will be issued by the Geological Survey of Canada, for whom the work was undertaken.

The object of the investigation was to ascertain, as far as possible, which of the geological formations in the area referred to contained clays or shales of economic value, and consequently special attention was given to those that appeared to be promising. But since in most cases it is difficult to tell much about a clay or shale from its appearance, a number of samples were collected for laboratory tests. In describing the results of the work, it seems best to take up a discussion of the clays by formations, treating the deposits of the two provinces separately.

NOVA SCOTIA.

The geological formations of Nova Scotia range from the Pre-Cambrian to the Triassic, and they are nearly everywhere overlain by a mantle of Pleistocene material of variable thickness. In certain formations the character of the material is such that

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there is little probability of its being of any value to the clay-worker; others, however, contain a large number of Argillaceous beds.

Formations of no great Value to the Clay Worker.

Pre-Cambrian.—The Pre-Cambrian, which includes crystalline rocks of either igneous or metamorphic character, underlies a large portion of south-western and southern Nova Scotia proper, a large portion of northern Cape Breton, and also scattered areas in south-eastern Cape Breton. None of the pre-Cambrian rocks are of plastic character, nor do they become plastic when finely ground. While they have, no doubt, weathered down to residual clays in the past, these have been largely removed by glacial action.

The only deposit of residual material known to the writer is a small pocket on Coxheath mountain, near Sidney, the clay there having been formed by the decomposition of a light-coloured felsite, rather common in that region. The deposit is too small to be of any economic value; but in recent years several attempts have been made towards utilizing the felsite itself in the manufacture of fire brick.

This rock, however, could not possibly be used alone for brick making, even though its refractoriness is fair, being equal to cone 27. In order, therefore, to utilize it, some form of binder such as fire clay, would require to be added.

Basing an opinion on the writer's own observations, supplemented by inquiries, there is no clay in the Sydney area sufficiently refractory to mix with the felsite. The latter, however, might be mixed with clay from other localities. With this idea in the mind, the following three mixtures were tried:—(1) 75% felsite (ground to pass 20 mesh), 25% Hussey Drift clay Inverness; (2) 50% felsite, 50% Hussey Drift clay; (3) 50% coarse (3-16 in.) felsite, 50% Shubenacadie fire clay. In every case a good hard brick resulted at cone 5, and it is probable that less than 25% of clay might be used. If the Inverness clay were used for this purpose, felsite could be obtained near that town.

Silurian.—The rocks of this system underlie a narrow area on the south side of the Annapolis valley and irregular areas in

the eastern half of Pictou and northern half of Antigonish counties. They are of economic importance because of the deposits of iron ore they contain. Associated with these are somewhat extensive beds of shale, but most of the material is rather slaty in its character and of exceedingly doubtful value for the manufacture of burned-clay wares. Some of those associated with the Clinton ores near Arisaig were tested, but were found to be rather low in their plasticity, although of low fire shrinkage and good red colour when burned. Their only possible use would be for mixing with some of the Carboniferous Limestone shales found along Bailey's Brook, in Pictou county.

Devonian.—The Devonian rocks underlie a narrow belt of irregular width extending through the central part of the province, some small areas in south-western Cape Breton to the north east and south-west of St. Peter's bay, as well as on the north-eastern side of the Straits of Canso, near Hastings.

These rocks were examined at a number of localities and were found to be either too schistose in their character, or, where of argillaceous nature, contained too much silica, present either as disseminated sand in the shale, or as interbedded sandstone layers. Were it not for the sandstone layers, the material, though siliceous, could no doubt in some cases be used for brick manufacture.

Permian.—This includes: (1) a series of disconnected areas extending from Chignecto Bay, along the north shore to a little beyond Merigomish harbor; (2) an area south of Joggins; (3) a small area near Sackville. No shales of any value were found in it, but there are some clay deposits north-east of Woodburn, which, according to Poole's geologic map, lie in the Permian conglomerate. They are, however, quite different from any materials found in the Permian at other points, and since the smaller scale map published by the Geological Survey places the southern boundary of the Permian a little farther north, these clays may lie in the Millstone Grit.

Whatever their geological location, these deposits of clay near Woodburn are of great interest.

One deposit lies about one mile, 10° S. of W. from Woodburn station, and outcrops in the bottom and bank of Small Brook. It is a shaly clay, covered in places by glacial drift, and said to show the following section:—

Section of Clay Deposit on Small Brook, near Woodburn—

Glacial drift	Variable.
Red clay	4 ft.
Mottled red and whitish clay	11 ft.
Red clay	125–150 ft.

This clay (No. 1507, table) burns to a buff brick of good colour and hardness, if not heated higher than cone 3. Above that it develops small fused spots, but holds its shape up to at least cone 9. Its fire shrinkage and absorption are both low. It is not a fire clay, but could be used for pressed brick, and perhaps paving brick.

Another good clay (No. 1501 table) is a red and mottled shaly one found about three-quarters of a mile northeast of Woodburn station. This deposit is not less than 15 or 20 feet thick, and could be opened up for some distance along the outcrop without working into the hill to any great extent. While not a buff-burning clay, still it gives a good red brick for ornamental purposes, and would, it is believed, also work for drain tile.

Triassic.—The Triassic rocks underlie one belt that follows the Annapolis Valley, and another one along the north shore of Cobequid Bay, tapering out east of Truro. They are usually sandy in their character, and, as far as have been determined, cannot be considered as a source of either clay or shale.

IMPORTANT CLAY-BEARING FORMATIONS.

From the above statements it will be noted that the formations likely to yield clay or shale deposits of value must be the Lower Carboniferous, Millstone Grit, Coal Measures and Pleistocene. These are few in number, but nevertheless they underlie areas of considerable extent.

Lower Carboniferous.—Underlying as it does a rather extensive area in central Nova Scotia, and another one in Cape Breton, it is to be regretted that the Lower Carboniferous has not been more widely investigated by clay-product manufacturers. The formation has strong possibilities, however, and should be carefully examined, but it cannot be expected to yield plastic ma-

terials at all points, especially where it is composed largely of conglomerate. The so-called Carboniferous Limestone member is the most promising.

Many shales associated with the gypsum beds are quite plastic, but in places these are highly ferruginous, and many contain impurities such as concretions of gypsum, etc. They might be used for common brick manufacture, provided these impurities were eliminated by screening or rendered more or less harmless by crushing.

Small samples tested from a few points showed that these shales were usually red-burning in their character.

At times the Lower Carboniferous limestone proper carries considerable shale. In some localities these beds are thin and the limestone predominates, while at others the shale beds show a strong development.

Pugwash, on the north shore, is the only locality at which these beds are being worked. Here the shale is utilized by the Maritime Clay Works for common and pressed brick. The shale pit of this Company is situated about two miles south of the town, on the west side of the bay. There is about 5 feet of glacial drift capping, under which lies the soft shale that may be dug with ploughs and scrapers. This is one of the best located deposits in Nova Scotia, and the product finds an extensive and ready market. The shale burns to a good hard red brick at a low temperature, and may be utilized not only for the manufacture of common brick, but also for face brick made either by the stiff-mud process and repressed, or by the dry press method. The weathered shale, or a mixture of weathered and unweathered material, gives the best results.

There is also an abundance of shale in the Lower Carboniferous limestone formation near Sydney, good exposures being found on Point Edward, on the west side of Sydney Harbour; but while the shale burns to a fair body, there are in these exposures too many sandstone layers to make it workable at a profit.

Northeast of Shubenacadie, on the Bloomfield farm, shales are found that are very plastic when weathered, but do not appear to be of much value except for common brick making.

Millstone Grit.—This formation is well exposed at a number of points, as follows:—1, in the area north of the coal measures

Out crops of Coal measures of red shale overlying jointed sandstone, west of Glace Bay.

Clay Pit of Mira River Brick Co., Mira River, C. B.

in the Joggins district; 2, north of the area of outcrop of the coal measures in the Pictou coal field; 3, south and southeast of Hawkesbury; 4, near Wallace in Pictou County; 5, north of Antigonish; 6, west and southwest of the Sydney coal field.

Speaking in general terms, one cannot predict the universal distribution of promising clay or shale beds in the Millstone Grit, but small beds are not uncommon. Unfortunately outcrops are scarce in many of the areas underlain by the rocks of this age, and this increases the difficulty of finding clay or shale beds in it.

North of Joggins, the Millstone Grit shows a continuous exposure in the cliffs along the Bay of Fundy shore; but the beds are mostly sandstones, with here and there a few thin shaly layers. Only one shale bed of importance was noted, and that was in the Grindstone quarry, about one mile north of the Joggins wharf. This bed is not more than 10 feet thick, nor is it well located for extensive working. If used, it would require to be opened as a long narrow cut.

In the Pictou coal region, some red-burning shales are found in the Millstone Grit just north of the Intercolonial Railroad and about half way between New Glasgow and Woodburn; but they are of doubtful value, partly by reason of the uncertainty of their extent. The overburden is, moreover, too thick to permit the clay being worked by open pit, and it is not of sufficiently high grade for underground working.

South of the Hawkesbury, along the shore of Canso Straits, shales are abundantly exposed, especially a short distance north of Bear Point. They are, however, not only too gritty to work well, but also contain too many sandstone beds. To the eastward toward Port Malcolm, where borings have been made for coal, sandstones predominate over shales.

There are some exposures of a soft shale in the Millstone Grit, along the shore road just west of Wallace, but they do not appear to be of high grade, nor would it be practicable to work them because of their proximity to the highway and houses in the neighbourhood.

One of the best shales found in the Millstone Grit is that outcropping along Bailey's Brook, northeast of Antigonish, in Pictou County. This has not been worked, but it burns to a good body at a low temperature, and might possibly be used for

paving brick. The main objection to it is its somewhat high fire shrinkage, which, however, might be reduced by mixing with it some of the Silurian shale from Arisaig. This did not seem to reduce the density or destroy the colour on burning.

Another drawback to the Bailey Brook material is that it lies too far from rail or water transportation. Yet it is probable that this same shale may be found in a more favourable location, since the formation extends northeastward to the shore, and southwestward to the line of the Intercolonial Railway.

The Millstone Grit occupies a rather extensive area to the east of Sydney and borders the coal measures on the west, southwest and south, a strip projecting to the shore on the north side of Cow Bay. Along this shore the outcrops are mainly sandstone and show no shales of importance nor are there any good shale exposures on the southeast side of Sydney Harbour between Sydney and Victoria Mines. Inland the exposures are scarce, and while shale beds are said to occur, the only one observed was in the Ashby Pit, on the border of Sydney. Here the Dominion Iron and Steel Company has made an opening to obtain clay for stopping the tap holes of the blast furnace, taking their supply in part from surface clay, and in part from the weathered outcrop of a 12 foot layer of clay shale, underlying sandstone. The lower four feet of this are somewhat sandy.

The tests made on this (No. 1509 of table) proved it to be a buff-burning material of good colour, yielding a hard product at low temperature. It is not, however, a fire clay as has been suggested, but may be regarded as a good pressed-brick clay, and, if properly weathered, might also serve for pottery. Its refractoriness is among the highest of any tested from the Sydney field, not excluding the coal-measure clays and shales. The extent of this bed is not known, as glacial drift covers the outcrop, but little ditching and boring would be required to ascertain its probably continuation along the strike; although the situation is such that for any considerable production, it would be necessary to employ underground methods.

A similar clay is said to occur at the base of the hill behind the coking plant of the Dominion Iron and Steel Company.

Coal Measures.—As was expected, these were found to represent the most important clay and shale-bearing formations in Nova Scotia, and were, therefore, somewhat carefully examined.

Since it is a common custom among miners to call every coal under-clay a fire clay, the investigators received many statements regarding the existence of fire clays in the several coal fields; but the only clay associated with coal that proved to be of refractory character, was that overlying the 13 foot seam at Inverness.

The most abundant exposures, and most extensive deposits of the coal measure shales and clays are found in the Sydney region, and may, therefore, be first mentioned.

Sydney Field.

In this district the shales and clays form an almost continuous series of outcrops from the Big Bras d'Or to Cow Bay, the only interruptions being at a few points, where the land surface is low and covered by drift, and at Cape Percy on the northeastern shore of Cow Bay, where the Millstone Grit extends to the shore line and cuts out the coal measures. Owing to the almost uninterrupted line of cliffs along the shore a fine series of exposures was obtained.

By way of general explanation, it may be remarked that the Sydney coal region is divided into several parts by several deep, northeast-southwest bays, and consequently it is somewhat difficult for geologists to correlate the sections in the several subdivisions of the field.

It may be stated, however, that the coal beds are interstratified with shales and sandstones, the whole series being bent into a number of gentle folds, forming the bottom of a broad trough dipping out under the sea. Low dips prevail throughout the field, thus giving fairly broad outcrops in many cases; but still the dip is sufficient to carry a bed rapidly under cover.

Towards the northwestern and southeastern ends of the field the sandstone beds predominate and the shales are of poorer quality, that is to say, they are very gritty; but in the central portion, representing the higher beds, the shales are as abundant as the sandstones.

The shales themselves range from fairly smooth, fine-grained, plastic shales of gray or red colour to others quite siliceous in their character and of doubtful value.

Now although the aggregate thickness of the shale beds is high, few of the individual beds are very thick; indeed, there is

frequently a rapid alternation of shales, sandstones and sandy shales.

In the final report to be issued by the Geological Survey of Canada, these shales and clays will be described in detail, and it will suffice here to call attention to only a few of the more important occurrences. They are as follows:—

1. On Cranberry Head, near Sydney mines, there is a deposit of shale not less than 20 feet thick, dipping out under the sea. The overburden is not too thick to prevent its removal. Some of the layers are a little sandy and may even contain small, scattered concretions of iron carbonate, as well as coaly fragments, but on the whole the material is rather smooth and plastic and burns to a good hard brick at a low cone. Judging from the result of tests, this shale might possibly be used for pressed brick; for manufacture as paving brick it would appear to be a promising material. (See sample 1508.) Underlying this is a more sandy shale, which could be used in brick manufacture.

2. On the north shore, immediately to the west of the base of Cranberry Head, and at the foot of "No. 2 street," Sydney Mines, is exposed a low-dipping bed of soft reddish shale, not less than 20 feet thick, and passing under a more sandy, grayish shale. This red shale (see 1519, table), which for purposes of identification and because similar beds outcrop at other points to the westward, is termed the Cranberry Head type, is one of the best red-burning shales in the Sydney region. It gives a hard red body when burned to cone 05, shows a low absorption and moderate fire shrinkage. It worked up either by the wet or by the dry process.

3. Just east of the entrace to Glace Bay Harbour there is a good outcrop of a brownish sandy shale (See 1514, table), forming a bed not less than 10 feet thick, with little overburden. Its appearance is not very promising, but the material when ground or weathered develops good plasticity and gives a hard, red brick after burning at cone 010 (1050°C.).

4. One of the best clays found in the Sydney region, is that underlying the coal in the Toronto mine of the Colonial Coal Company, near Little Bras d'Or Bridge. As exposed at the time of the writer's visit, it was but 12 to 15 inches thick, but there is, of course, a possibility that it may thicken. The material

is very plastic clay, of good tensile strength (See 1526, table), burning to a buff body with a good ring at cone 03. It worked well when wet moulded, but it is not stated that it would work on a dry-press machine. The clay stands cone 9 (1310°C.) without fusing; but it is not a fire clay.

To summarize, it may be said of the coal-measure shales of the Sydney coal region, that: 1. There are a number of deposits, although not of unlimited size, that might be used for common or red-pressed brick. 2. One, at least, many serve for making paving brick. 3. One buff-burning clay was found. 4. No true fire clays were found, although nearly every "lead" was carefully followed up.

Pictou Field.—In this field are numerous shale beds associated with the coal seams, but they appear to reach their greatest development in the central portion of the area, and the most important occurrences at present known are higher up in the coal measures than the coal beds. A strong contrast exists between the shale beds of the Pictou area and those of the Sydney region, for the first-named are much thicker and do not contain as many sandstone layers.

Many of these shales when ground and mixed with water are of strong plasticity, but have the disadvantage of often containing a considerable percentage of carbonaceous matter, and also scattered concretions of iron carbonate and limonite. Both may cause considerable trouble in the burning, and some manufacturers have had costly experiences before they learned how to treat the shales containing them. A few of the shales are too high in carbonaceous or petroliferous matter to be used at all, and are classed as oil shales.

No less interesting and important is the fact that there may be considerable difference in the refractoriness of two beds not far apart in the same section, and not differing greatly in appearance from each other.

As the results of the investigators' study of the shales in this field, the writer considers it important to state that these materials should be carefully prospected, since it is not unlikely that good shale deposits not yet utilized occur in the central portion of the area. A careful search would necessitate much boring and test pitting.

Some of the heaviest deposits are found along McLellan's Brook, a tributary of the East River, and the beds have been opened up near New Glasgow for making salt-glazed sewer pipe, fire-proofing and brick. The material used (See No. 1504, table) is a carbonaceous shale that burns to a hard body, but will not stand much more than cone 3 and requires to be handled with the greatest care in burning, on account of its high carbon contents. It is sometimes mixed with glacial clay, but this reduces its heat-resisting qualities. Another bed, also along McLellan's brook, has been used for brick manufacture, and burns to a buff colour. It also stands considerably more heat than the preceding, not fusing before cone 14.

The only other shale worked is near Westville, where an undershale in the Drummond Colliery is used for making a stiff-mud repressed brick, sold for various purposes, and commonly known as a fire brick.

This is a somewhat hard shale occuring under the No. 3 seam, that burns to a hard brick, and stands cone three without fusing (See No. 1506, table). It suffers from a high carbon content and hence must be burned with great care. There is no reason why it could not be used for pressed brick.

Among the unused deposits that were tested from this region, was a plastic shaly clay, underlying the Cage or Deep seam near Stellarton, and sampled on the outcrop. This could be used for red-brick manufacture, but is not refractory as it is past vitrification at cone 3. Another deposit outcrops further down Coal Brook towards the Allan shaft. The clay is also fairly plastic, but like the preceding is red-burning.

Inverness Field.—This small field carries a number of shale beds associated with the coals, but few are of great thickness, indeed none of them are equal in size to those worked in the Pictou area. Outcrops are abundant along the shore both north of the mines and south of McIssac's pond, whose sand-plugged outlet is an impressive reminder of former attempts to keep an open harbour at this point.

The best clay in this region, and it is one of the best found in Nova Scotia, is a bed of gray, plastic clay overlying the 13-foot coal seam, and is found at several points where that seam is exposed. The bed varies in thickness from 18 inches to 3 feet,

is free from grit and of high plasticity. (See No. 1553). When subjected to firing tests it was found to burn to a hard, dense body of buff colour, held its shape well up to cone 9, and did not actually fuse completely until cone 25. It makes a satisfactory dry-press brick, and could no doubt also be used for stoneware, and also be used in the manufacture of asbestic. A sample tested from another outcrop gave similar results.

Few shale beds of promise outcrop along the shore, the beds being mostly sandstone but one somewhat heavy bed lies just south of McIssac's pond, under a coal seam. The shale, which is very smooth and plastic, is buff burning but not refractory.

Port Hood Field.—Here too there are scattered shale occurrences in both the Millstone Grit and the coal measures, but few of them are of any thickness, and the most important occurrence is along the shore a short distance north of Judique Harbor, where a bluish gray, vertically dipping, shale, 8–10 feet in thickness outcrops for some distance along the shore. It is one of the smoothest shale clays found in the coal measures, and since it is very plastic and dense-burning at a moderately low cone, it could perhaps be best utilized for making drain pipe, or red earthenware. There is hardly enough to support a brick plant.

Joggins Field.—This field contains a number of shale beds, but the objection to them is their thinness and frequent alternation with sandstone beds. There are one or two thick deposits, but they contain too many sand seams to be of value.

A hard shale forms a parting between the splits of the Joggins seam, and in places reaches a thickness of 3 feet, although at others it may pass into sandstone (See No. 1563, table). This, although hard, grinds down to a fairly plastic mass and makes a good red brick, but it is not refractory, since it fuses a little above cone 3.

Pleistocene Clays.—These may be roughly divided into two classes, viz., (1) glacial clays, often of stony character, but very plastic, tough, and red-burning, and (2) Marine clays, often strongly laminated, but also quite plastic and red-burning.

At the present time these two types of clay are used almost exclusively for common brick. At a few points drain tile and some pressed bricks are made, and at one locality pottery. These clays might be employed for roofing tile. The glacial clays are found at

scattered points and are worked mainly in the Cape Breton region (See Nos. 1512, 1525, table). Marine clays were not as widely observed. They are best developed in the Shubenacadie and Annapolis Valleys.

Along the Shubenacadie river these clays are found underlying the broad terraces which border the river on one or both sides. They vary somewhat in their character, being at one point very smooth and plastic, so that they are suitable for pottery or tile making (See 1520, table); at others more sandy, and adopted to brick manufacture. (See 1503, table). They are in every case red-burning and make a good product, but do not stand a high degree of heat. In the Shubenacadie Valley, a pottery is in operation at Enfield, and brick yards at Elmsdale and Shubenacadie.

The occurrence of Marine clays, of good plasticity, laminated character, and burning to a red colour, are known at a number of points in the Annapolis Valley. They are worked at Avonport, Middleton and Annapolis. These clays are used mainly for common brick, and to a lesser extent for drain tile. Some of the smoother beds could be employed for making cheap art pottery of either glazed or unglazed character. The result of a test of these Avonport clays is given in the table, No. 1564.

Clays of Undetermined Age.—A most remarkable clay deposit and one of undetermined age, is that found at Shubenacadie and in the Musquodoboit Valley. The material is a highly plastic clay, of whitish, dark gray, or mottled red and grayish white colour, covered by a variable thickness of glacial drift.

Attention was attracted to these deposits some years ago, because of the highly plastic and highly coloured nature of the clay, but few attempts have been made to utilize it, although some was used for pottery at Enfield, and for fire brick at Westville.

Deposits are known to occur in the Musquodoboit Valley between Middle Musquodoboit and Elmsdale, a distance of six miles, and beyond that especially along Paint Brook. The best known occurrence is on Murphy's Brook near Middle Musquodoboit.

The following records of borings made by Mr. Keele indicate its mode of occurrence:—

Section on property of Norman Deal, west bank of Paint Brook, near Elmsvale, P.O.

	Ft.	In.
Soil.	1	0
Bright red clay.	8	0
Mottled red and gray clay.	3	0
Gray sand.	1	0
Mottled red and gray clay.	8	0
Coarse dark red sand.	0	6
Mottled red and gray clay.	3	6
	25	0

Sections on Murphy Brook, near Middle Musquodoboit. No. I, 225 feet above G .T. Reed's house. No. II, 400 feet up stream from No. I.

I			II		
	Ft.	in.		ft.	in.
Gray clay.	17	0	Red and gray clay.	20	0
Silty clay.	4	0	Gray clay, sand and lignite.	1	6
Red and gray clay. . .	1	0	Dark gray clay.	2	0
			Red and gray clay.	1	6
	22 ft.			25	0

From several borings made on Murphy's Brook it is estimated that there may be a total thickness of not less than 50 feet of this clay.

The clay, which is of fair refractoriness, burns to a cream colour, and hard body, its total fire shrinkage even at cone 9 not being excessive. Tests of the clay are given in the table, Nos. 1566 and 1561.

The material could be used in the manufacture of fire brick and pottery; but at present it is rather inaccessible, being 18 miles from the railway.

At Shubenacadie on the Intercolonial Railway, the same clay was first discovered in a cutting. Subsequently a shaft was sunk through the glacial drift and the clay penetrated at a depth of about 20 feet. The thickness there is not less than 26 feet.

NEW BRUNSWICK.

As most of the field season was spent in Nova Scotia, but little time remained for investigation in New Brunswick. Several areas were visited, however, and the following general observations may be presented:

In the vicinity of Albert mines in Albert county, are some very promising beds of Devonian shale that burn to a red brick. These overlie the oil shale.

Other red-burning shales of Lower Carboniferous age are found in the same vicinity, and samples tested from the deposits on Weldon Creek, show their value for brick manufacture.

The most important Carboniferous clays and shales were those found in the Grand Lake coal-mining district, 25 miles east of Fredericton.

The coal mines are situated on the northern side of Grand Lake, the localities at which coal is mined for shipping being on the New Castle River, and Salmon Bay. The National Transcontinental Railway traverses the area, the principal station being at Chipman on the Salmon River.

The coal seams where mined, are found at depths varying from a few feet to 60 feet below the surface, the shallower seams being mined by open pits, and the deeper by drifts or shafts.

The coal seam, which is about 30 inches thick, is overlain by 8 to 10 feet of hard gray shale, and underlain by 4 or 5 feet of rather soft clayey shale. The beds are nearly horizontal. Much of the top shale is removed in mining while the floor shale is commonly left.

Samples of these shales were tested from several localities (1601, 1602, 1610, 1611) and some yielded excellent results.

That from the Evans Mine, near Salmon Bay, yielded especially good results, burning to a fine, buff, speckled product. Another fine shale is that from Flower Cove, which also burns to a buff product. Shales of plastic character are found both under and over the coal at Beersville, 12 miles southeast of Harcourt, but are not of refractory character.

CLAY WORKING INDUSTRY.

Up to the present time the clay deposits of Nova Scotia have been but little developed. Common brick are made at Annapolis,

Middleton and Avonport in the Annapolis Valley region, and at Shubenacadie, and Elmsdale in the Shubenacadie Valley. Other yards are in operation at Sylvester, New Glasgow, Pugwash, Eden Siding, and Mira River. In most cases these are operated to supply a rather local demand, although the Annapolis and Pugwash brick are sometimes carried some distance by water. Common pottery is made from the smoother phases of the marine clays south of Elmsdale. Most of the common brick yards re-press a few bricks. A hard brick, known in the trade as a fire brick, but not really such, is made from the Carboniferous shales at Westville. Sewer pipe, flue linings and drain tile are made from the shales at New Glasgow, and some drain tile are manufactured in the Annapolis Valley. If much development occurs the markets will be mainly outside of the province, except for common brick. At present the buildings in that region are constructed mainly of wood, but as the supply of timber becomes scarcer and more expensive, brick must be looked to as a substitute. For outside markets the plants should be located as near to water as possible to avoid the costs of rail transport.

The laboratory tests have shown that many of the Nova Scotia and New Brunswick clays and shales can be utilised for pressed brick manufacture, and as there are practically no producers of pressed brick eastward of Ontario, the rewould appear to be a good field for enterprise in this direction.

Laboratory No.	Locality.	Plasticity.	Air shrink. per cent.	Av. tensile strength, lbs. per sq. in.	Cone 010 (950° C)		Cone 05 (1050° C)		Cone 03 (1090° C)		Cone 1 (1150° C)		Cone 3 (1190° C)		Behaviour at other Cones.	Colour after burning.
					Fire shr.	% abs.	Fire shr.	% abs.	Fire shr.	% abs.	Fire shr.	% abs.	Fire shr.	% abs.		
1518	Felsite from Coxheath Mt with 25% Hussey clay, Inverness	Good	5	—	1.6	.....	0	.....	.....	.....	.....	.....	.....	.....	Cone 5, Fire shr. 0, Abs. 9,22%	Buff
1509	Millstone Grit, clay shale, Asby Pit, Sydney, C, B	Good	9.2	148	1.2	11.24	4.3	6.75	5	6.40	5	3.83	.....	3.43	Swells same at cone 5	Buff
1612	Red Shale (Lower Carboniferous limestone), Bailey's brook, Pictou Co., N.S.	Fair	4.3	—	.....	9.5	.....	4.0	—	—	.....	.2	.....	.....	.....	Red
1508	Run of Clay Shale deposit Cranberry Head, Sydney mines.	Good	6.	85	1.7	15.01	4.3	8.3	4.6	6.46	5.6	1.35	5.6	1.45	.....	Red
1502	Clay under coal, Atlantic Coal Co., Pt. Morien, C.B.	Good	5.6	64	.4	17.25	3.3	12.32	5	9.88	6	3.52	.....	.....	Beyond vitrification, cone 3	Red
1514	Shale (coal measures) east of entrance to Glace Bay Harbour, C.B.	Low	5.7	52	.3	13.12	1.6	10.48	3.3	2.27	5.1	1.54	Beyond itr'n.		.....	Red
1519	Red coal measures shale, north shore, base of Cranberry Head, Sydney Mines, C.B.	Fair	5.2	71	0	14.00	5.3	5.71	7	2.24	Beyond vitr'n		.....	.....	.....	Red
1526	Toronto Mine underclay, near Sydney Mines, C.B.	Good	7.7	129	.2	16.10	5.	6.52	6.	1.87	7.3	.21	Fused.		.....	Buff
1504	Coal measures shale, Standard Drain Pipe Co., New Glasgow, N.S.	Fair	5.5	107	– .3	14.20	3.6	6.81	.....	6.9	6	0	.....	.....	.....	Red
1506	Shale under No. 3 coal seam, Intercolonial Coal Co., Westville, N.S.	Fair	3.6	56	0	11.03	2	9.19	1.3	8.08	4	4.80	5.0	5.04	Cone 5, abs. 1, 8	Buff
1517	Shale, Brooks yard, New Glasgow, N.S.	Good	5.	98	0	11.42	2.3	8.43	3.6	7.57	6	2.04	5.	.90	Cone 9, abs. 8	Buff

1528	Shale, under cage on Deep Seam, Stellarton, N.S..	Good	5.	69	.8	15.14	3.3	12.2	5.6	4.3	5.7	4.9	4	2.26	Beyond vitrification at 3	Red brown
1553	Clay from 13 ft. seam, Hussey Drift, Inverness, C.B.	High	8.5	206	.3	15.74	4.3	9.79	.....	2.25	6.6	.....	7.3	0	Cone 5, fire shr. 10, Abs. 0%, Fused 2.5	Buff
1554	Shore S of McIsaac's Pond Inverness	Good	5.7	145	.8	12.13	2.6	9.61	6.6	3.18	6.6	1.8	5.	0	.....	Buff to Red brown
1558	Coal measure clay, S. of Port Hood and N. of Judique harbour.....	Good	5.8	65	.2	20.52	7.6	4.94	12.3	1.51	9.6	.11	Beyond vitr'n.		.....	Red
1563	Shale from coal mine, Joggins, N.S.	Fair	5.	58	.6	10.0	3.6	5.0	3.	6.72	.....	.....	Fused		.....	Red
1507	Mottled Clay, Small's Brook, S.W. of Woodburn, N.S.	Good	7.6	190	.3	12.6	1.3	9.93	4.	9.73	1.3	4.14	2.7	2.42	Cone 5, Fire shr. 3.3%; Abs. 2.15 %	Buff
1501	Mottled Clay, ¾ Mile N.E. of Woodburn, N.S.	Good	6.	157	.3	12.75	3	10.33	3.3	8.14	4.3	1.77	5.	1.54	.....	Red
1565	Shaly clay from brick works at Pugwash, N.S	Good	6.	75	.1	14.53	3.6	8.31	7.3	2.95	.....	.....	.....	.....	.....	Red brown
1522	Shubenacadie fire clay, N.S..	Very Good	6.3	110	—.1	.....	.6	.....	1.6	.....	2	.....	3	.....	Fuses completely co. 30	Buff
1566	Grey clay, Murphy's Br, Mid. Musquodoboit, N.S..	High	6.8	81	.4	19.3	2.3	16.71	6.	15.92	6.	7.41	7.	7.71	Cone 9, Fire shr. 8; Abs., 4.34	Cream
1561	Mottled clay, same locality	High	6.5	68	.1	21.68	2.6	18.29	6	12.96	6.3	7.0	6.3	5.41	Cone 9, Fire shr. 9%; Abs. ,23%	Cream
1503	Brick clay, Elmsdale, N.S	High	6.3	143	4	14.20	9.6	6.81	4	6.9	Fused				.....	Red
1520	Pottery clay, Enfield, N.S.	High	8.3	226	1.3	11.81	7.6	.20	8.3	.027	Fused		.....	.....	.....	Red
1512	Brick clay, Eden siding, C.B.	High	7.7	230	1.3	16.24	4.3	9.85	5.0	7.62	Fused		.....	.....	.....	Red
1564	Brick clay, Avonport, N.S.	High	7.2	145	2.2	11.36	5.	6.43	6.6	2.96	Fused		.....	.....	.....	Red

Laboratory No.	Locality.	Plasticity.	Air shrink. per cent.	Av. tensile strength, lbs. per sq. in.	Cone 010. (950° C)		Cone 05 (1050° C)		Cone 03. (1090° C)		Cone 1. (1150° C)		Cone 3. (1190° C)		Behaviour at other cones.	Colour after burning
					Fire shr.	% abs.	Fire shr.	% abs.	Fire shr.	% abs.	Fire shr.	% abs.	Fire shr.	% abs.		
1525	Glacial clay, E. of McKinnon's Harbour, C.B. . .	High	7.6	222	.4	14.27	2.6	9.92	3	10.19	3.6	.96	Fused		.....	Red
1567	Lower Carboniferous shale, Weldon Creek, Albert Mines, N.B. . . .	Fair	5.6	74	1.1	13.14	1.3	11.22	1	13.15	.....	.....	.....	.....	.....	Red
1560	Carboniferous shale, over oil shale, Albert Mines, N.B.	Fair	6.2	137	.3	13.00	.6	14.55	1	13.37	5.3	7.32	Fused		.....	Red
1601	Under clay, C. C. Co., Salmon Bay, N.B.	Low	4.8	Low	0	10.2	3.6	4.6	2.3	2.63	2.3	.75	.....	.....	.....	Red
1602	Over-clay, same place...	Fair	4.7	62	0	12.6	2.	9.19	2.3	7.78	.....	.....	.....	.....	.....	Red
1603	Weathered shale, Flowers Cove, N.B.	High	8.6	201	.3	15.70	1.3	14.10	1.6	12.69	5.	8.87	.....	.....	Cone 5, Fire shr. 7.7; Abs. .26	Buff
1608	Same, 70 feet in from outcrop, ...	High	8.2	252	.3	12.37	1.6	11.97	2.	11.06	2.6	8.09	.....	.....	Cone 5, Fire shr. 4.33; Abs. 5%	Buff
1562	Brick clay, Fredericton, N.B.	Good	7.8	109	.2	22.08	3.6	1.69	10.3	.....	nearly fused		.....	.....	.....	Red
1710	Shale over coal, Evans Mine, Minto, N.B.	Low	3.5	—	1	11.5	4.3	3.7	—	—	4.3	1.4	.....	.....	.....	Red
1611	Shale under coal, Evans Mine, Minto, N.B.	Fair	3.8	—	.3	15.0	.6	13.6	—	—	1.0	10.7	1.6	10 0	Cone 5, Fire shr. 2; Abs. 8%	Buff

Discussion.

Mr. Dresser:—I was very glad to hear Dr. Ries' statement that he expects to be able to locate clay that will be of use in the manufacture of asbestic. At the present time a small amount of asbestic, to the value of about twenty thousand dollars a year, is manufactured from clay with a binding of short asbestos fibre. The demand for this article as a fireproof plastering material is very considerable; but the clay necessary in its manufacture has been of almost prohibitive price, due to the necessity of transporting it from New Jersey to the asbestos mines in southern Quebec. If by this investigation Dr. Ries has been able to locate clays nearer to the mines or easier of transportation, he will have accomplished a very important step in the utilization of low grade products of the asbestos mines. Personally I was much interested in Dr. Ries' paper, especially as he has dealt with a rather neglected subject.

Prof. Baker:—I think the great future of the clay industry in Nova Scotia lies in the utilization of the shale beds rather than the loose clays of the surface, since the latter vary so rapidly and within such short distances. An apparently perfectly homogenous clay bed will alter in one hundred yards into an entirely different class of material totally unsuited for the manufacture of products for which the first mentioned clay was utilized.

I think that in those compact clays immediately underlying the Pleistocene loose deposits, referred to by Dr. Ries, we have an accumulation of infinite value to this country and particularly to the Eastern section, on account of the close association there with the smelting industries of Eastern Canada.

Mr. T. W. Gibson:—The Institute, I think, should consider itself very much indebted to Dr. Ries for his paper.

I would like Dr. Ries to explain in a few words to us the conditions upon which the plasticity of these beds depend. During the reading of his paper he mentioned a number of shale beds that were plastic and some that had not this characteristic.

Dr. Ries:—Plasticity is a property of clay concerning which we are still somewhat in the dark; but, so far as we can tell at the

present time it is ascribed to two causes. It appears to be due in part to the fineness of grain of the material and in part to the presence of what we call colloid matter. We can detect the presence of these colloid substances in clays. Many mineral compounds assume a colloidal form, and if the clay contains much of that colloidal matter and it has also a very fine grain, the clay seems to have high plasticity. Now, if there is very little colloidal matter in the clay, and the clay is very coarse grained due to much sand, the plasticity is low. Very fine sand, like the finest of flour, will show plasticity to a very minor degree. Consequently sand is usually referred to as a non-plastic substance. The reason that some of these shales are low in plasticity is due, I think, in part to two causes—partly to the fact that they contain a great deal of sandy matter—and many of those sand grains are rather coarse—and also partly to the fact that the shales have been consolidated in some degree by a cementing action. We find clay grains often bound together into large grains by some form of cement, such as iron oxide, or silica.

RECENT MINING DEVELOPMENTS ON THE SKEENA RIVER.

By W. W. Leach, Ottawa, Ont.

During the past few years prospecting has been quite extensively carried on over a large area of country tributary to the projected line of the Grand Trunk Pacific railway, in the Skeena river district, and numerous claims have been recorded here.

In a paper contributed to the Institute by the writer in 1907, special reference was made to the copper, copper-silver and coal properties on the Telkwa river. The development work undertaken in the district since that date has been inconsiderable and only a few new claims have been staked. The explanation of this is found in the statement that owners of prospects consider it inadvisable to further develop their properties until the railway shall have been completed, when operations may be carried on much more economically.

Meanwhile, prospectors have not been idle; but have devoted themselves to exploration in other parts of the district, with the result that numerous discoveries have been made in widely separated localities.

Three localities that have attracted chief attention during the past three years, are the Hudson Bay mountains, the Babine range and Nine and Six-mile mountains near Hazelton. At all these points the ores of silver-lead occur most freely and are usually found in small but often high grade veins.

The writer has not visited the Babine range; but is in a position to state that in the other localities mentioned the geological conditions are very similar to those obtaining on the Telkwa; the prevailing rocks being of volcanic origin heretofore known as the

Porphyrite Group and consisting of andesitic flows, breccias, tuffs, etc. These rocks have been invaded by a number of granitic masses that have dike shattered and altered the volcanic beds. The ore is found near the contacts of or in or alongside of dikes from the intrusive areas.

On the Hudson Bay mountains, more particularly on their western slopes, a number of claims have been located and here much prospecting has been undertaken.

The northern parts of these mountains is composed of rocks of the Porphyrite Group—chiefly volcanics, but including, near the summit, some sedimentary beds, all very severely folded and crumpled. Towards the southern end of this group of mountains there is a large intrusive area of granite-porphyry. Most of the more important finds have been made in the volcanics, but in close proximity to the granitic masses.

Coronado Group.—This property has been somewhat extensively prospected by open cuts, by means of which the vein has been traced for the length of two claims. The ore occurs in what appears to be a dike from the intrusive porphyry area, striking about north-east, and having a nearly vertical dip. The strike conforms very closely to the slope of the mountain, which is here very precipitous.

In one cut made a lens of almost pure galena was exposed. A specimen of this ore assayed: gold $1.20; and silver 62·63 oz., to the ton. In other cuts, higher up the mountain, the ore shows much less galena, but the mineralization is as a rule, fairly heavy. In one opening, in which the walls were not reached, 4 feet of ore, consisting of galena, blende, arsenical pyrites, pyrites, and lead carbonate in a quartzose gangue but all much decomposed, was exposed; and a sample from this cut assayed as follows: gold $10; silver 3 oz., to the ton.

Near the eastern boundary of the Coronado, on the west bank of Sloan creek, a similar and parallel ore body has recently been discovered. Here a lens of galena, nearly pure, although carrying a little blende and chalcopyrite, has been uncovered. The greatest width of solid ore is 14 inches. This vein has been traced about 200 feet along the strike to the north-east; but as only the surface dirt has been removed in two or three small holes, the character

of the ore could not be definitely observed. A specimen of the solid galena assayed: gold $4.40; silver 36·47 oz., to the ton.*

Victor Group.—The Victor group, consisting of the Standard, Victor and Triumph claims, is situated to the west of the Coronado. The ore occurs in and along the east wall of a dike of approximately 60 feet wide, striking about north-east, and dipping at 80 to 90 degrees south-west. By open cuts the vein has been traced up the hill for a considerable distance. In the lowest cut about 3½ feet of ore is exposed, consisting of galena, blende and pyrites, irregularly and rather sparsely distributed in a gangue of altered dike rock and a little quartz. The ore appears to follow a line of faulting and shearing parallel to the walls of the dike. Fifty feet up the hill the ore has narrowed down to about 8 inches, with 3 inches of clean galena, a specimen from which assayed: gold, trace; silver, 43·33 oz., per ton.

Again at a still higher elevation, the dike where exposed by cuts shows rusty and decomposed. Here its width varies from 12 to 60 feet and the mineralization is strongest along the hanging wall. In one of these cuts about 2 feet of ore, composed of blende, arsenical pyrites, with a little galena and chalcopyrite was observed. At the highest opening on the mountain, about 2½ feet of ore is exposed, here highly decomposed and consisting of stringers of galena, associated with much lead carbonates. A sample from this point gave the following assay: gold, 20 cents; silver, 39·20 oz. per ton.

Dominion and Newcastle Group.—The Dominion and Newcastle claims are located on the east bank of Sloan creek and near its source. On this property a heavily mineralized dike of about 6 feet wide cuts the country rock, which is greenish and greyish andesite. The chief constituents of the ore are blende, arsenopyrite, iron pyrites, a little chalcopyrite and a very little galena, in a gangue of altered dike rock and much quartz.

Two samples were taken here, the first of the general run of the ore, while the second was from a band of almost pure arsenical pyrites. The results by assay are as follows: (1) gold, $5.80, silver, 12·40 oz.; (2) gold, $3.60, silver 0·55 oz.

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* The assay results above quoted are from returns made by the Mines Branch of the Department of Mines, Ottawa.

Humming Bird Claim.—On the Humming Bird claim very little work has been done (by no means sufficient to prove the extent of mineralization). It includes, however, several small cuts, of which the chief is about 15 feet wide, and does not reach either wall. The rock is much decomposed, while on the surface is a considerable accumulation of a black, earthy material, which in the laboratory proved to be largely pyrolusite. Beneath this decomposed material the ore is blende, arsenical pyrites, galena, and iron pyrites in a felsitic gangue of altered dike rock, much shattered and brecciated; the mineralization being irregular and somewhat sparse. An assay of a sample from this cut gave the following results: gold 60 cents; silver 10·37 oz., per ton.

Babine Range

The Babine range claims have not been visited by the writer; but, probably, more development work has been done here than in any other locality in the district. The ores are silver-lead, the best known property being the "Dibble" group, which is being opened by Mr. Jas. Cronin who has systematically prospected the claims during the past three years.

Nine-mile Mountain

The most important recent development has been the opening up of a number of silver-lead veins on Six, Nine and Twenty-Mile mountains north of and quite near Hazelton. The rocks here appear to be a northern continuation of the Porphyrite group of the Telkwa river and Hudson Bay mountains. There appears, however, to have been a gradual change from south to north from beds of purely volcanic origin to aqueous deposits, as shown at Six and Nine-Mile mountains, where the beds are of sandstones and shales, though composed largely of volcanic material. Hence, since the term "Porphyrite Group" here applied might appear misleading, the more general designation of "Hazelton Group" is adopted to distinguish these rocks.

In this vicinity the sandstones and shales of the "Hazelton Group" have been cut by at least three comparatively small

masses of intrusive granitic rocks, and it is around the peripheries of these areas that the ore is found.

As these discoveries were made late in the autumn of 1908, little development has been possible; but sufficient has been done to encourage owners to actively prospect their claims.

The veins occur, as a rule, either in fissures in a hardened sandstone, near its contact with the granitic areas, or in sheared zones in the granitic mass itself. In one case (that of the "Era" on Six-Mile mountain) the ore appears to follow the contact.

A short description of the chief prospects is here appended:—

Silver Cup.—This claim, one of a group of four, is located on Nine-Mile mountain about six miles north of Hazelton. The ore occurs near and to the east of an important granitic area, in a highly altered sandstone, in places approaching a quartzite. The strike of the vein is about north 30 east with a dip of 73 degrees south-east, while the country rock strikes south 50° west and dips 15 degrees north-west. Two open cuts have been made on this claim, in the lower of which the vein is 1·2 feet in width, between well defined walls. The vein matter is nearly solid galena, in association with a little stibnite, arsenopyrite, blende and white quartz.

The following assays of this ore, were made by an official in the employment of the Canadian Consolidated Mining and Smelting Company:—

	No. 1	No. 2	No. 3
Gold	Trace	Trace	Trace
Silver	181·0 ozs.	268·2 ozs.	187·4 ozs.
Lead	70·0%	50·0%	58·4%

The second cut lies about 200 feet farther south. Here the vein widens to about 2·5 feet. The ore, however, is not so solid, there being less galena present, but more stibnite and much more quartz.

The "Silver Dollar" claim is included in the same group as the last mentioned. Conditions here are similar to those at the Silver Cup, and it is possible that it is the same vein. It is here 3.2 ft. wide, where cut, the ore being a milk white quartz, carrying disseminated crystals of arsenopyrite, a little stibnite, iron pyrites and a very little magnetite.

Other claims now being developed are the "Hazelton," "Sunrise," "Lead King" and "Era." Assays of samples of solid galena from the "Sunset," yielded from 115 to 125 ounces in silver; and from 65% to 75·5% lead.

While on the "Era," the vein on the hanging wall shows very heavy mineralization for a width of from eighteen inches to two feet, being almost solid sulphides of antimony, lead, arsenic, silver and copper.

COAL.

During the past few seasons many claims have been staked but little or no development work has been undertaken on the majority of the coal properties. It would appear that, in general, the known coal areas lie in comparatively shallow synclines, the overlying rocks being, as a rule so soft that they have, offered little resistance to erosion.

From the Kispiox river to the mouth of the Telkwa many patches of the coal-bearing beds are known; but, from present available information, it would appear that in no case do the seams fulfil all the necessary conditions for successful exploitation, viz.—workable size, adequate superficial extent and quality.

To the south, however, on the headwaters of the Morice river, two new areas have recently been discovered. The most northerly of these, on Goldstream, has an extent of about 2½ by 2 miles. The following analyses by the Mines Branch, Department of Mines, are from samples taken from open cuts:—

	Moisture	Vol. Com. Matter	Fixed Carbon	Ash
(1) 8 ft. seam . .	4·67	30·55	55·23	9·55
(2) 6½ ft seam. . .	6·36	28·36	58·75	6·53
(3) 3½ ft seam. . .	6·86	27·24	59·47	6·43

* Coke—non-coherent in all cases.

A short distance to the south of this area, on Clarks Fork of the Morice, another important basin is situated. This area has not been prospected to a sufficient extent to definitely determine the boundaries; but sufficient work has been done to indicate that it has a probable length of at least eight miles, and a width of from ¾ to 1 mile.

The analysis given below is of a wet and decomposed surface sample (afterwards air-dried). It may be confidently expected that the percentage of moisture, and probably of ash, would be materially reduced were a sample to be obtained under more favourable circumstances:—

Moisture	Vol. Comb. Matter	Fixed Carbon	Ash.
10·81	31·22	48·62	9·35

Coke—non-coherent.

This seam is about 10 feet thick.

WORK OF STATE GEOLOGICAL SURVEYS.

By H. FOSTER BAIN, San Francisco, Cal.

(Annual Meeting, Toronto, 1910.)

Official geological surveys had their origin in the attempt to bring to the service of the practical engineer engaged in public work, all the aid that the scientific geologist had to offer. At first the geologist was only called in for particular examinations, much as specialists are even now only employed at intervals by many mining companies. It seems to have been supposed that by some mysterious process a geologist could learn all that was needful in the course of a single and usually brief visit. When the Erie canal was projected, Amos Eaton, one of our foremost pioneer geologists, was employed under the direction of Stephen Van Rensselær, to study the route. In 1824 his report on a 'Geological and Agricultural Survey of the District Adjacent to the Erie Canal' was published. It was, so far as I know, the first official geological survey undertaken on behalf of any American State. The report was typical of the times and of the undeveloped state of the science, but it was also typical in that it was an earnest and measurably successful effort to make useful such science as the geologist then had. This attitude has been especially characteristic of the leaders of American geology from that time to this, and to it is due the exceptional measure of public support which geologic study and investigation has enjoyed in this country.

Early exploring expeditions, both in the United States and in Canada, usually included in their personnel some one trained at least in the elements of mineralogy and geology, and the efforts of these pioneers did much to promote the rapid development of our two countries. The inherent disadvantages of discontinuous and unsystematic work became in time apparent, and regular

geological surveys were established. In Massachusetts action was taken in 1829 when Edward Hitchcock was employed to map the geology of the State, a commission that resulted in the publication of his preliminary volume of 1833, followed by the more complete reports of 1841. In New York, in 1836, was authorized the organization of the great State survey which in one form or another has continued its work to the present, and which seems likely to find a field of usefulness for an indefinite period in the future. At this epoch the Southern States, instead of being the poorer sisters of our commonwealth, were rich and prosperous. They were leaders in all directions, and naturally made haste to take up the new work. In the thirties and forties most of them devoted some portion of their public revenue to the systematic study of their geology and resources. Geologists were, however, few, and methods were far from perfect. The science itself was young and foundations were still being laid. The early State geologists were often gifted with more enthusiasm than balance. They were generally interested more in the science as a science than in public service. Just as it required time for scientists to learn that public funds can only be devoted to research when adequate returns are made, so it also required time for the public to learn that no safe application can be made of a science which does not stand firmly on a broad foundation of pure research. This adjustment between scientific thought and public opinion has been slow, and at times the situation locally has been most discouraging. There was, none the less, steady progress toward the recognition of mutual responsibilities, and in the United States the surveys which have done the best practical work have been those which have also done the best scientific work. The two lessons which the history of State surveys in this country has taught most clearly are, first, the need of continuity in the work, and second, that there can be no divorce between practical and scientific studies if good results are to be achieved.

At present, in the United States, thirty-six of the States support some sort of a geological survey. In addition there is the great Federal bureau having its headquarters at Washington. Outside the United States conditions are so dissimilar as not to permit of exact comparisons. In Canada, Ontario alone, in its Bureau of Mines, supports an organization corresponding to our

State surveys. In some of the other Provinces a nucleus of such an organization exists, and the Canadian Geological Survey, in functions and methods of work, closely resembles the United States Geological Survey. Canada is young, and much remains to be done in organizing and supporting geological work within her borders. In Australia each of the States maintains a bureau which makes geological investigations, though there is as yet no survey of the commonwealth as a whole. New Zealand has an excellent organization. The Geological Survey of India corresponds in character more to the United States or the Canadian Geological Survey than to our State bureaus. In South Africa the work is still in the stage of limited commissions to study particular problems and areas, such as that of F. H. Hatch in Natal last year. It is hoped that the new Union of South Africa will either organize the work adequately or stimulate the States to do so. In Germany the larger states quite generally maintain geological surveys. Outside these countries the dual form of government is so little developed that geological work where undertaken is usually regarded as national in character.

In the United States we find no great difficulty in discovering plenty for both State and National surveys to do, and I think there is sound reason for maintaining both State and National organizations. It is not merely a matter of securing local development or of responding to local patriotism. A great Federal organization in many particulars can do work more efficiently than a number of local bureaus. Here as elsewhere there is some economy in organization in large units, but this view, pushed to the extreme, loses sight of one of the fundamental features of geological work; namely, that geology is a science, and that a science to serve a useful purpose must constantly be fed by research. Now to research, criticism is not only stimulating, it is essential; and a number of independent centres of research are vastly better than one single institution, no matter how richly supported and wisely administered. Research depends on development of individuals, and genius must be given free rein to be productive. Administration of a scientific bureau must always be different from a police bureau, and the efficiency which comes from centralization may well cost too much. In the United States relations between the National and the State surveys have

been very generally cordial. Men, methods, and results have been fully interchanged, and no one familiar with the situation as it has developed in the last quarter of a century, can doubt that this action and re-action between free units has been immensely stimulating and helpful to all concerned. Even our poorest State survey serves at least a useful purpose, as an example of how not to do it.

It may have been noticed that so far I have had much to say about geological surveys, but have not attempted to define exactly their function. The reason is that different surveys do different things, and that fashions in surveys as in hats, are local and subject to change. The early organizations necessarily devoted much attention to strictly scientific work, particularly along paleontologic lines. Of recent years technology has been receiving more attention, and there has been everywhere an increasing attention to detail. In a general way American State surveys are rarely charged with much responsibility of administrative character, especially in police regulation. In this as in all else there are exceptions. The State Geologist of Indiana has the appointment of coal mine inspectors, of natural gas inspectors, and formerly appointed oil inspectors. Recently a move was made to place the mine inspectors of Missouri under the Bureau of Geology and Mines, as the Geological Survey is there officially designated. In Kentucky the State Geologist is at the same time Chief Mine Inspector. In other States surveys have occasional traces of police power, but in general, experience and argument are against this form of organization. The two sorts of work are so different that it has usually been found better to organize them separately.

In a broad way American State surveys are occupied with three sorts of work: (1) Areal mapping; (2) Special investigations; (3) Bureau of Information work. The areal surveys involve topographic as well as geologic mapping, and may be general and systematic, designed to cover the whole area, or of special areas. Instances of the latter are where, as in Illinois and Mississippi among others, funds appropriated for the survey of swamp lands with a view to reclamation, have been placed under charge of the State Geologist. As between areal mapping by State and Federal officers there is no consistent difference. State maps are both

better and worse than those made by the United States Geological Survey. As a whole they do not average as well in quality and generally they are more utilitarian and less expensive. Notable exceptions exist.

The special researches undertaken by State Surveys are extremely varied. Reports on the food of fishes, and the strength of building stones; the cost of road making, and the methods of utilizing peat; paleontologic monographs, and physiographic models; all these and many more, come from the survey offices. Investigations of any sort relating to the occurrence and distribution of the mineral wealth of a territory, are considered germane to the work. In many States the broad subject of natural history is included and, particularly of recent years, methods and costs of utilizing materials have come in for investigation. The relative emphasis placed on these different subjects is determined by local conditions and the personal interest of the executive officer. The wise administrator studies this problem carefully and gets all the support he can for the problems of most local importance, fighting to keep the work as symmetrical as conditions will allow, and giving way when he must, with hope that his successor may be more successful in attracting attention to the less popular phases of the work. A number of the earlier State organizations were wrecked by persistent publication of ponderous paleontologic tomes when the public and the legislative powers were asking for results of other work. The American public at least, is not narrow or ungenerons, and so far as my personal experience and observation go, is willing to support the so-called 'scientific' phases of geological work to the limit of its ability of the moment, provided only that economic phases of the work be not neglected. Geology and geologists have prospered greatly in America, but it has been because they have made some return in usefulness to society. Theoretical geology could not have received for its purposes the large sums of public money which it has enjoyed, except because of the corresponding development of economic geology, nor could economic geology have come into being on any other basis than that of well-matured theory.

Methods used by geological surveys are as varied as is the work itself. In general any method which promised results has been followed. Whether it were studying microscopic slides or

burning paving brick the choice has been wholly one of purpose and means. One possible exception exists. The surveys have done little actual drilling. There has been a general hesitancy in the United States to adopt this simple and effective method of putting theories to test. I do not believe this has often been due to any disinclination to have theoretical conclusions tested as promptly and vigorously as possible. It follows rather from the fact that in most States private initiative can be relied upon for the drilling after the geologist has pointed the way. The expense of thorough drilling is so great, and the benefits to the land drilled when successful are so definite, that it has been generally thought better to use the always limited funds in some other way. In Missouri appropriations were at one time made for drilling but little definite good was accomplished. It may be confessed that at that time conditions were not favourable for good geological work of any kind in Missouri and a trial now might well bring larger results. In New York, I understand, drilling has recently been done by the State Geologist to good purpose in proving the extension of the Clinton iron ore under cover; a matter of large scientific and economic interest. In Ontario the Bureau of Mines has done extensive work with the drill. Abroad geologists have been less chary about drilling, especially in Australia. Here, again, conditions differ, since the State retains its interest in minerals and is really a partner in the enterprise. Probably in America, geological surveys in time will come to more liberal use of the drill.

The Bureau of Information work is one of the most important duties of a survey. The State Geologist finds much of his time taken up with inquiries from landowners, investors, promoters, and, indeed all sorts and conditions of men. Often much valuable time must be devoted to an inquiry of doubtful importance, but a public officer should serve the public faithfully, and one of the most useful purposes of a survey is that of dessiminating correct information about the natural resources of the State. Proper records, and some preliminary attention to systematization of data, will save much time and vexation in this work.

There are two other phases of survey-work that demand a word; first, the relations of geological surveys to the recent lively interest in the conservation of our natural resources, and second,

their relations to bureaus of mines, where the latter exist. Geological Surveys have a very definite relation to the conservation movement and a large responsibility thereto. In the main they have been the most important agencies in collecting the information upon which the movement rests, at least as relates to mineral wealth. This was strikingly shown in an argument by James A. Tawney, of Minnesota, before the House of Representatives at Washington, July 27, 1909. It was all the more interesting in that Mr. Tawney was then using his friendliness to the United States Geological Survey as a defense against the charge of unfriendliness to the conservation movement. Yet it was barely two years since he had made every effort to cut down the appropriation for the Survey and cripple it in almost every branch. From an unfriendly critic he had become an advocate, because he found the organization an effective agency for collecting the data necessary to proper legislation along conservation lines. As collectors and students of facts of especial importance in this connection, geologists must have a large part in bettering conditions for the tomorrow. Their responsibility to the public requires that they be diligent, impartial, and fearless in this work, and it is my personal belief that geologists will gain by allowing to others the responsibility for administration of the laws which result. He is a better critic who is not committed.

The relations of a State Geological Survey to a Bureau of Mines, where the latter exists, must clearly be determined by the law enacted in each case. There are, however, certain general principles which it is desirable to have enacted into law where possible. Ideally, the geologist deals with minerals in place, and all questions relating to their distribution and mode of occurrence should be exclusively his. The mining of the ore, its milling, smelting, and marketing, are the duties of the mining engineer, and it will be well when possible to divide the work along these lines. There is also another difference to be observed. The geologist deals with rocks. His work is that of the investigator. The mining engineer also deals with rocks, but in addition must always take into account the human element. He must be prepared to do what he can with frail human nature to help, and necessarily he studies compromise more than does the geologist. It follows that if the mining engineer be not less an investigator

than the geologist, he is at least more of an administrator, and investigation should be dominant in a Geological Survey, while administration must lead with a Bureau of Mines. I would not suggest, however, that a Bureau of Mines should not spend generously for investigation. Indeed it must do this or the bureau will die of dry rot and become the acme of officialism and all that we deprecate in 'bureaucracy.' The chief of a bureau of mines has a wide field for investigation, but his methods must differ from those of the geologist.

In conclusion I may state that I have expressed freely and frankly, here, my personal convictions on many points where there is wide room for honest difference of opinion. In doing so I have no thought of being dogmatic, but rather of giving the results, as I see and interpret them, of experience on our side of the purely political line which divides Canada from the United States.

THE UNITED STATES GEOLOGICAL SURVEY*

By ROBERT H. CHAPMAN, Washington, D. C.

(Annual Meeting, Toronto, 1910).

Previous to 1879, four organizations under Federal control and support had been making explorations, maps, and geologic investigations of the United States. These four, briefly known as the "Hayden Survey" the "King Survey," the "Powell Survey," and the "Wheeler Survey," which had devoted entire attention to western areas, were discontinued about 1879, and in that year the present United States Geological Survey was established. This Survey has since forwarded the work begun by the earlier organizations and has enlarged the area of operations to include the whole country. The growth of the Survey has been vigorous and the scope of the work entrusted to it by Congress has broadened greatly since its creation. The annual appropriations have increased from $100,000 the first year to approximately a million and three-quarters dollars. The primary purpose of the Survey, to which its first efforts were largely confined, was the geologic mapping of the United States, and to carry out this purpose it was soon found necessary to hasten the topographic mapping in order to provide a base for the use of the geologists in the field.

The demand for the Survey's topographic maps continually increased, as they were found to be invaluable to engineers and capitalists in developing the natural resources of the country, in building railways, roads, and canals, and in locating power plants and transmission lines; and to legislators, State and National, in the discussion of the many questions involving topographic

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* Published by permission of Director, U. S. Geological Survey.

UTAH

(1). This photograph shows the type of country in which coal beds are found.
(2). Geologist at work, mouth of coal mine
(3). The classification of Lands—Geologist studying coal bed about 8 ft. thick, near Arvada

knowledge on which they were called to pass. As these maps became better known, individuals gradually came to make use of them in journeying across country with which they were unfamiliar—a use that has very markedly increased since the advent the modern motor car.

As specific instances of the use of these topographic maps by state authorities, the following may be cited: The engineers of the Board of Water Supply of New York City made large use of them in determining the general features of their work, and those of the New York Stage Barge Canal consulted them freely in investigating the water supply available for the maintenance of the water level in the several sections of the canal. The Railway Commissioners of Pennsylvania use them constantly to inform themselves of the surface conditions under which the railroads operate.

In several cases a computation of the contents of reservoirs based on these maps has shown an error of less than 10 per cent when checked by later detailed surveys, certainly an excellent showing. A group of maps have often saved many times their cost in anticipating preliminary surveys in road, ditch, or railway construction. The location of many important bridges may be predetermined within a short distance by their use. In California an engineer whose office and records had been destroyed in the San Francisco earthquake and fire hastened to Sacramento and offered $5 for a single map, the price of which was 5 *cents*.

The Survey maps have been made on a systematic plan in regard to scale and relief expression which has been carried on, with minor changes in detail, for nearly thirty years.

In regions that are thinly populated, with few roads and long distances between settlements, the field work partakes of the nature of exploration and the maps may be referred to as reconnaissance maps. For this purpose a scale of about 1 inch to 4 miles is used very satisfactorily, and a contour interval of 100 or 200 feet is usually sufficient. Mapping on this scale proceeded rapidly in the earlier work in the Western States and is now done in such regions as Alaska and the deserts of Nevada and California, where the maps have guided many a wandering prospector to his destination, to water and food, or to help in case of accident, and have no doubt saved many lives.

In parts of the country that are further developed, a scale of 1 inch to 2 miles, with elevations expressed by 100-foot or 50-

foot contours, has been found serviceable in advancing the location of routes of travel, in laying out railway rights of way, and in establishing approximate boundaries for government reservations, national parks, and national forests. In some States many hundreds of square miles supposed to lie in one county have been found to belong to another by careful location on these maps of a mountain ridge, stream, or watershed, which by law was the dividing line.

In areas where settlement is thicker and "culture", as the works of man are called, more important, a scale of 1 inch to 1 mile, with contours at 50 or 20-foot intervals, is adopted. On such maps all isolated houses are shown and all towns are carefully drawn to scale, together with a large amount of detail indicating the meandering of streams, the curves and turns in the roads, and the forms of the smaller ridges and valleys. On all maps the roads are distinguished as first or second class, so aiding the traveller in choosing his route.

Maps of much larger scale, known as "special maps," are made of many small areas of great interest. The necessity for such maps may arise from the particular importance of some natural object, such as geysers or springs; the call for detailed information in connection with a great engineering structure or problem, such as the drainage of swampy lands, the reclamation and utilization of flat areas like the Sacramento Valley of California or the Yazoo Delta of Mississsippi, or the irrigation of farm lands, or the detailed study of a mining district. The scale of these special maps ranges between 500 and 2000 feet to an inch, and the relief is shown by contour lines with an interval of a few feet only—usually between 5 and 20 feet, according to the ruggedness of the area to be mapped. The maps show the shape of buildings, the width of streets and alleys, the car lines in the towns. The mine maps give the location of prospect holes 6 feet or more in depth and of the great "dumps", the accumulations of waste materials or low-grade ore brought from below the ground, which appear as hills, many of them several contours high.

In making these maps many points are accurately located by triangulation based on astronomic positions. This triangulation is essential to the correct placing of the areas mapped; it determines the horizontal adjustment of one map to all others and is of

(*U.S. G. S. Photo*)

(1). Triangulation in the Plateau region.
(2). Tule growth, Sacramento Valley, California.
(3). Plane-table workers and Packers on Dall river trail.

(*U.S. G. S. Photo*)

(1). Topographer at work on summit, 5,500 ft., Mt. McKinley region, Alaska.
(2). Chief Geographer at work on edge of cliff, Yosemite Valley, California.
(3). Surveying Cache slough, lower Sacramento Valley.

great value in locating and marking the civic boundaries, which may be in dispute, as many of them follow imaginary lines defined in position by latitude or longitude. The completion of triangulation in any area, therefore, may affect the income of States, counties, or towns, inasmuch as by showing the correct location of such boundaries it may indicate where the payment of taxes should be made. The Geological Survey corps of topographers have established between 5000 and 6000 such stations, besides utilizing many points located by other organizations. In this connection it is interesting to note that the triangulation of the Coast and Geodetic Survey has been used by that bureau to determine the amount of horizontal displacement due to the San Francisco earthquake.

The common datum for heights is mean sea level and to determine the relation of different points to this datum carefully leveled lines are carried in circuits checking on themselves and on one another and forming a net, upon which bench marks of stone or iron are placed. To these marks all the work in their vicinity is referred. By this means the vertical position of all points may be shown on the map and also the correct relation to all oher areas mapped is determined. In one instance the changes of level in buildings in a city undermined by the excavation of ores was shown to be, though large, far less than was currently reported in sensational journals, and so this work has affected the value of land and surface improvements. That this is a great undertaking may be deduced from the fact that in the thirteen years in which it has been carried on about 150,000 miles of line have been run and an average of one permanent bench mark to every 3 miles has been established.

The topographic mapping of about 35 per cent. of the area of the United States has been accomplished and is represented on 1873 maps, which are all available to the public, some in a preliminary condition but most of them engraved and printed in the final form.

It may be seen that the topographic work is essentially the foundation upon which all the other work of the Survey and much private work is based.

WORK OF MAP ENGRAVING.

For many years the maps issued by the Survey were engraved and printed by contract. It was found after thorough trial that

there were numerous disadvantages in this plan; principally delay and excessive cost that, it was believed, could be overcome only by having the work done within the bureau. The Survey Engraving Division now engraves and prints its own maps, topographic and geologic, as well as many thousands of maps and charts for other Governmental bureaus, such as the Land Office, the Forest Service and the Government Printing Office. Of its kind it is probably the greatest map-making establishment in the world, and none other turns out more perfect products.

GEOLOGIC WORK OF THE SURVEY.

The topographic map is used as a base for all of the principal geologic mapping, the geologist, therefore, usually following, though occasionally accompanying and in rare instances preceding, the topographer.

The primary purpose of the study of areal and structural geology is the preparation of the geologic map of the United States showing the distribution of geologic formations at the land surface, and their attitude and position below the surface. It may, at the same time cover a comprehensive study of the mineral resources or may be simply intended to furnish a basis for further study of the economic geology, by showing the surface and underground distribution of the formations with which the mineral deposits are known to be associated. For example, if the region contains coal or oil, it is highly important that the underground structure be accurately determined so that the depth to a particular stratum may be predicted within a few feet at any point on the area mapped.

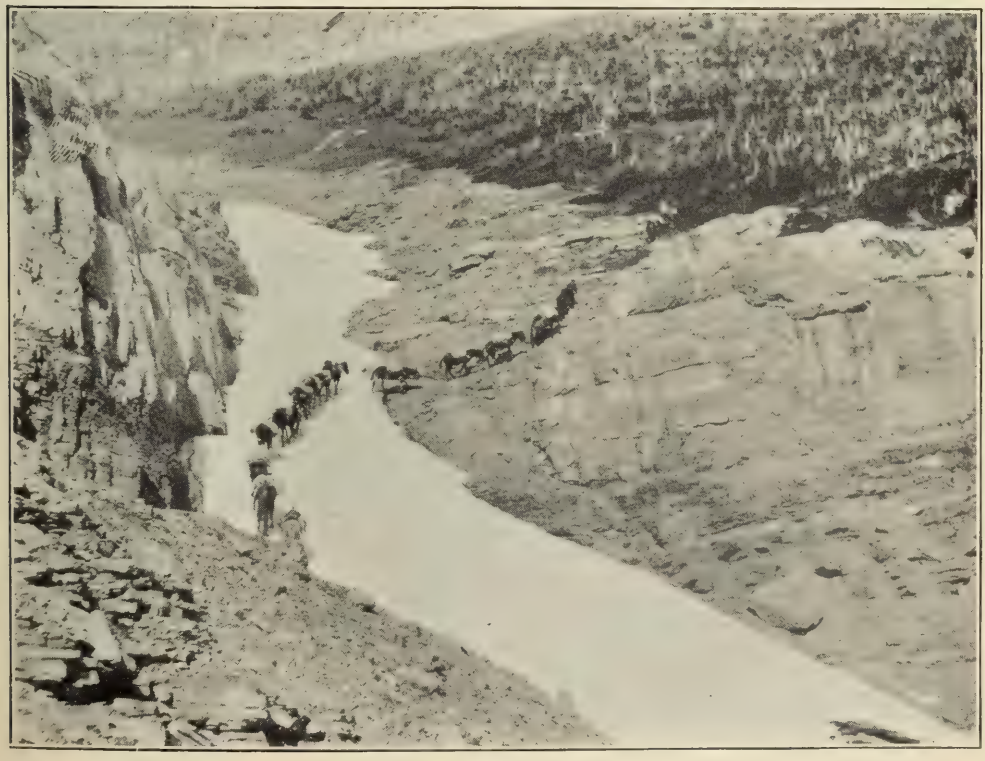
Maps resulting from this class of field work have a great variety of uses. They are adapted to educational purposes, to the economical and conservative development of mineral deposits, to the determination of water supply, both surface and underground, to the location of roads and road materials, to the study of character and distribution of soils, to the study of forests and reforestation, the classification of public lands, etc.

PETROGRAPHIC AND PALEONTOLOGIC STUDIES.

Rock specimens gathered in field work often require careful examination, the Petrographic division is entrusted with the mak-

(*U.S. G. S. Photo*)

Topographic Party in the mountains of Montana.



(*U.S. G. S. Photo*)

Pack train near Swift Current Pass, Montana.

(*U.S. G. S. Photo*)

Mode of transportation in Rio Grande Valley, New Mexico.

(*U.S. G. S. Photo*)

Transportation in Alaska—On Dall river trail. The packs varied from 60 to 125 lbs.

ing of thin sections for microscopic examination, to determine their nature. This is of primary importance in the study of the complicated rocks of igneous, or volcanic origin, since many of our valuable ores are associated with them, and many hundreds of specimens are prepared annually in the laboratory for the geologists to examine.

The determination of the age, history and correlation of the sedimentary rocks often depend largely upon the study of the remains of the animal and vegetable forms which lived during their formation and are now found as fossils. This work of the paleontologist in itself is essential in correctly mapping the areal geology, but it has other valuable uses.

In the perusal of a purely scientific subject it is not always possible to foresee the economic value, or its application to questions of moment to the nation and people; and the study of fossils, and their surroundings, does not seem of import to the layman, but it is a fact that the work of adequately classifying the public coal lands in the plains region of the west would have been well-nigh impossible, but for the paleontological work which for years preceded and which still accompanies it. Over great areas the rock has such similarity, yet locally such differences, that no horizon suitable as a datum upon which to correlate the work in widely separated fields could be found, except by the identification of the beds as established by the fossil contents. To do this experts in this branch of geology of necessity devoted years of patient study in the office and labour in the field, and the benefits are now evident as the intensely practical subject of land classification is being taken up.

The paleontologist and petrographer are no longer content, as formerly, to work only in the laboratory, but appreciate the necessity of field observation. Their work can be done most advantageously in immediate co-operation with the work of the field geologist, for these specialists furnish the standards for classification and correlation on which the field geologist must rely.

ECONOMIC GEOLOGY.

The primary purpose of the work of economic geology is the determination of the geologic relations of particular mineral deposits. The study of areal distribution of formations and under-

ground structure is incidental to this object, though generally essential. The area covered by such work is usually more restricted than in areal geologic work and is done in greater detail and on a larger scale. In case of mineral deposits having wide distribution, as coal, the scale of the work and the methods which should be employed do not differ materially from those used in areal work except that more attention is given to the study of the coal itself, to its composition and its variation from place to place, and to all of the conditions which will effect its economical development.

In case of metalliferous ores, particularly of gold, silver, and copper, the area within which the geology is to be studied is usually confined to a few square miles, but within these limits it must be examined in an extremely detailed manner and all possible lines of evidence followed, both on the surface and underground. In such work no details of structure or petrology can be overlooked, for it is upon these that conclusions as to genesis and extent of the ores must rest.

The work of the economic geologist, or as he is sometimes called, the mining geologist, is clearly differentiated from that of the mining engineer who is concerned primarily with determinations of amount and value of ore in the deposit and methods of economical exploitation. The work of the former, however, is the basis for the most successful work by the engineer. Both functions may be performed by the same person yet they are quite distinct and separate.

LAND CLASSIFICATION WORK.

The organic act, creating the office of the Director of the Geological Survey, states:—" .... this officer shall have the direction of the Geological Survey, and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain."

For several years special efforts have been directed towards the classification of coal and other mineral lands. Coal lands are acquired under laws which state in effect that the *minimum* charge for these lands shall be $10.00 or $20.00 per acre according as they may be located 15 miles or less from a railroad. This was at first accepted as the *only* figure at which they should be sold. Examination has proved that in vast acreages coal lands are enormously

(U.S. G. S. Photo)

(1). Some inhabitants of the Bad lands, Past and Present—Montana.
(2). Alaska. Fresh meat supply—Skinning a caribou.
(3). Around a campfire in Death Valley, a hundred feet below sea level.

(*U.S. G. S. Photo*)

(1). Geologist at work in Alaska.
(2). Surveyors breaking through dense tule growth in Sacramento valley.
(3). Topographer at work on top of Sierra Nevada.

more valuable, and the present practice is to place upon them a fair valuation, based on coal tonnage, which, while it will not retard mining development will yet bring something like an adequate return to the Government. Thus in southwestern Wyoming, lands which were valued, under the general ruling mentioned, at $20.00 per acre, were examined by the geologists and a value of $50.00 per acre put upon them, while the experts employed by the Union Pacific Ry. Co., stated, under oath, that the lands were worth $300.00 per acre.

The higher grades of coal of coking value and the anthracite have to a great extent passed from Government control; but there are enormous areas of material suitable for domestic and steaming purposes on which more just returns should be made.

In determining the questions vital to this work, in order to make the results of permanent value, it is necessary that those entrusted with it should have a thorough training in structural geology and that they have frequent consultations with the paleontological experts as heretofore noted. It is estimated that there are about 80 millions acres of government coal land in the region west of the Mississippi River, and if upon classification of this enormous area the rate of increase indicated above proves to apply, it may be instantly seen that the wealth of the nation has been increased to figures many thousand times the cost of all the associated work of the Survey.

WORK IN PHYSICAL AND CHEMICAL RESEARCH.

The primary function of this Division of the Survey is to assist the geologists in the identification of the materials which they collect, and in the solution of geochemical and geophysical problems. Much of the work done has been analytical, and over 6000 analyses have been made representing rocks, minerals, ores, waters, soils, coals, and even such things as meteorites.

The rock analyses have been a special feature of the work, and are more than ordinarily complete. From twelve to twenty constituents are determined in each analysis, and the average summation error is only two-tenths of one per cent. From these analyses the mean composition of the earth's crust to a depth of 10 miles has been determined, both as to the elements present and as to the relative proportions of igneous and sedimentary rock.

Incidentally to the analyses of minerals nearly twenty new species have been discovered and described by the chemists of the Survey. Among the waters analyzed were forty from the Yellowstone National Park, and also a large group of samples from the saline and alkaline lakes of Nevada, Utah, California, and Oregon.

Some of the researches carried out in the laboratory have had for their purpose the experimental determination of the conditions under which metallic ores are deposited. Others have related to the chemical constitution of the natural silicates; a subject of theoretical interest to the chemist, and also significant in the study of metamorphism. The synthetic production of mineral species, now carried on in the geophysical laboratory of the Carnegie Institution, was begun in the laboratory of the Survey, which is, so to speak, the parent of the younger establishment. The physicists of the Survey have also done much work on the measurement of high temperatures, the physical properties of iron and steel, and the elasticity of rock-forming materials.

ACTIVE WORK IN ALASKA.

The work of investigating conditions in Alaska has presented especial difficulties. The field is so far from headquarters at Washington, the areas in which the parties must be entirely self-dependent are so large, and the variety of investigations which must proceed simultaneously, so many, that a special organization, almost a smaller "Survey," has developed. Beginning in 1895, when three men were sent to this field, the work has steadily grown, until now a dozen parties and a total of nearly fifty men are engaged in it each summer.

At first little could be done but to explore and map the major routes of travel and to give preliminary reports on the ores, distribution of mineral resources, geology, and conditions of travel, but by systematic effort great progress has been made, until at present more than 120,000 square miles have been mapped topographically on the 4-mile to the inch scale, and a number of maps on the 1-mile to the inch scale have been prepared. Geologic reconnaissance maps cover nearly 100,000 square miles, and detailed maps, some 2,000 square miles. The area of Alaska is 586,400 square miles, and it is evident that the above figures make a very favourable showing.

(*U.S. G.S. Photo*)

THE SILVER CHORD DUMP.

At Leadville, Colorado. An artificial Topographic feature.

A general summary of the geography and geology of the Territory has been published, as well as more or less detailed reports of practically all the important districts. In this work the needs of the miner and prospector have received first consideration, but incidentally much data has been collected on the broader geological problems.

The plan has been to first prepare general topographic maps of the more important regions and, using them as bases, delineate the broader features of the geology. Such maps serve as a guide to the prospector by designating the areas most likely to include commercially important mineral deposits. These maps are issued on a scale of four miles to the inch, with 200-ft. contours, in sheets which cover an area of 16,000 square miles.

In addition to these general maps, detailed topographic and geologic surveys of the more important mining districts have been made, such as the Juneau lode mining district, the Bering River coal field, the Nizina copper district, and the Fairbanks and Nome placer districts.

The text which accompanies these published maps presents accounts of practically every producing mining district in Alaska. During the past three years systematic investigation of the surface waters available for mining in some of the important placer districts has been carried on.

The development of mines, roads, and railways has progressed until what was believed to be as poor an investment as a government ever made has become a highly important factor of the nation's resources, Gold, silver, and copper are found widely distributed, and large deposits of coal have been discovered, some of it of high grade. There is a good prospect that tin and petroleum will become products of commercial importance.

ASSISTANCE TO MINERAL DEVELOPMENT.

In all these developments the work of the Geological Survey has played an important part. The general route of nearly every wagon road and railway, even most of the important trails, has been located by the topographic maps. Many of the ditches also have been laid by these maps, only final location surveys having been necessary. The records of stream gauging have furnished the engineer with accurate data as to available water supply.

Geologic investigation has more directly aided the miner and prospector. It was the Survey which first called attention to the tin deposits and which also pointed out the probability of the occurrence of the ancient beach placers at Nome which have since yielded millions of dollars in gold. In the Copper River region the loci of the copper deposits was mapped before any extensive discoveries had been made. The Alaska surveys furnish perhaps one of the best examples of the practical value of scientific investigations to the mining interests.

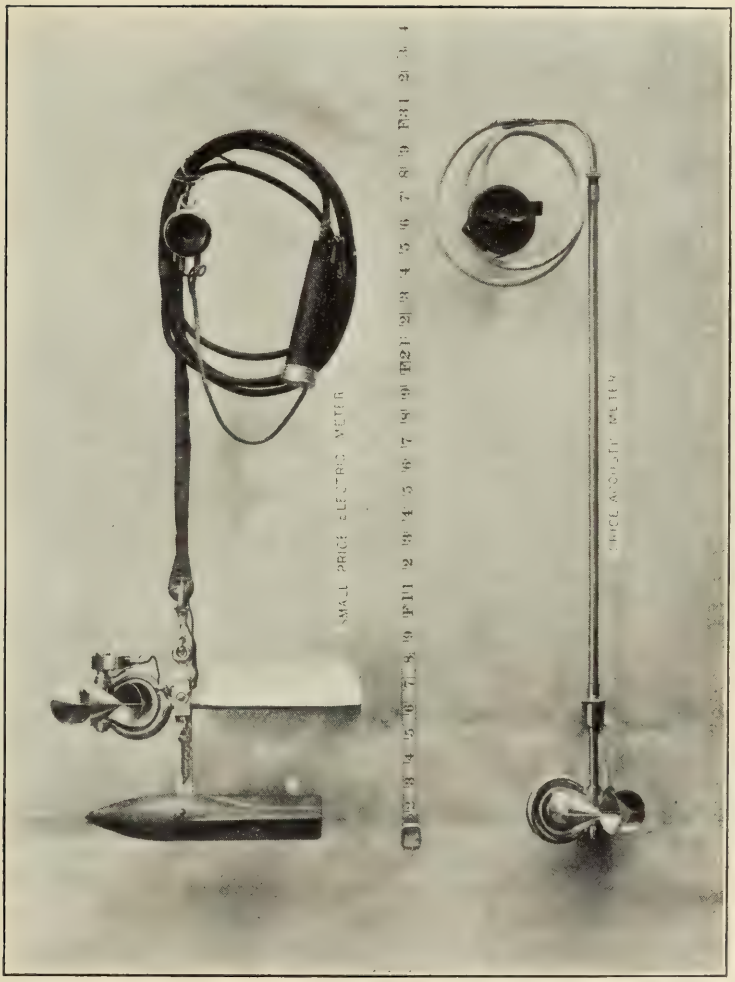
While this work has of necessity been expensive, owing to natural obstacles, the cost is decreasing in a noticeable ratio each year, and it has to date cost much less than one per cent. of the value of the mineral product of the territory, while the benefits and value have not only been immediate, but also permanent.

THE MINERAL RESOURCES OF THE UNITED STATES.

The gathering of information regarding the various mineral resources of the country was begun in 1882. In the beginning of this work only the more important lines were studied but the scope has been steadily enlarged to keep pace with the demands and the increasing number of the products. At first only coal, iron, and other such mineral industries were included, but later the work has been made to include gold, silver, lead, zinc, mercury, copper, graphite, mineral oils, natural gas, brick, tiles, cement, and building stones, and the list grows annually. The last four items are fast increasing in importance as may be suggested by the rapidity with which our structural timbers are increasing in value due to disappearing forests.

The work includes not only the items produced but the collection and publication of the statistics of production, and also the determination of the actual Mineral Resources, the possibility of the continuance of the production in the future.

There is a great and important factor to be noted in connection with the statement of the Mineral Resources. Such products as the precious metals and others are not destroyed in the using, and are to be counted among the resources, even after the exhaustion of all of the natural sources of supply, while such items as coal, mineral oils and gas once removed from the earth and put to service, like agricultural products are forever beyond recovery,



(U.S. G. S. Photo)

Electric current meters used by the Government. They are dropped into the stream and record the velocity.

(*U.S. G. S. Photo*)

HYDROGRAPHER GAUGING A STREAM

The meter suspender from the car is lowered into the water, every ten feet across the river, and the velocity of the flow recorded electrically. This velocity multiplied by the cross section area of the stream gives the total flow in cubic feet per second.

and may not be counted upon to be used again and again as can be the metal products.

The tremendous rate at which the destruction of the non-recoverable items is going on may be illustrated by the statement of the increase in the mine production of coal which in the year 1907 was 95 per cent. of the whole production in the United States from its beginning to and including 1897.

The location and study of the home-building materials, stone, cement, tiles, and brick, is of immense economic importance to the people of this as well as of future generations who are to seek shelter from the elements.

To establish and further in every possible way the economic development of our resources, to aid in locating and publishing any new sources of supply are important aims of this work, for it is evident that failure to make use of material, to leave it undeveloped and buried in the earth is in itself a waste.

To furnish the public with reliable results a considerable force is necessary in field-work. Facts are also gathered by the parties of other divisions and an enormous correspondence is maintained with producers in all parts of the country, involving over 200,000 letters annually, for it is necessary to list every mine in the country and to keep in continual touch with the owners.

The publication of this data is systematically issued in annual reports and special bulletins, and the information contained in these volumes is sought for and distributed to all parts of this country and to many foreign nations. The question of the supply and demand of a commodity, the ratio of prices are all closely related subjects upon which this data has an important bearing.

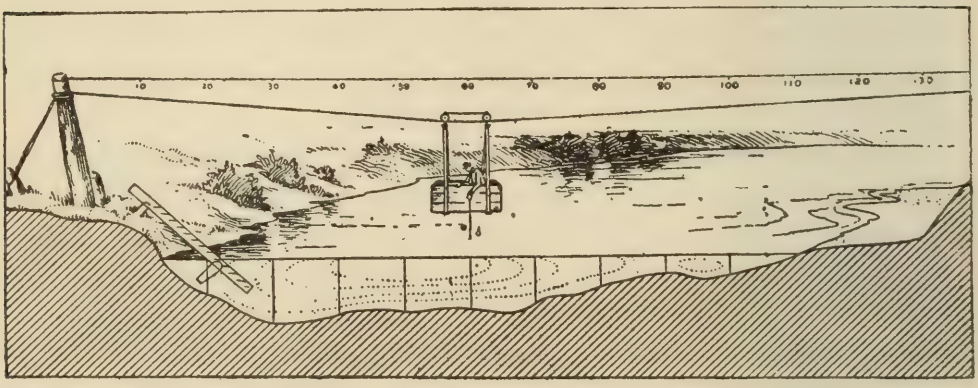
STUDY OF OUR GREAT WATER RESOURCES.

A most important wheel in the Survey machinery is the study of water supply. Much work is done in the field of stream measurement, rate and volume of flow, time of heavy flooding, etc., and stream gaugings have been made at over 600 stations, covering all portions of the country.

The data thus obtained are applicable in many ways and are of aid to many interests. For example, when considered in connection with the rainfall in a river basin (determined by the Weather Bureau) and its drainage area (obtained from the topo-

graphic maps) they are essential in the determination of the location and feasibility of power plants, storage reservoirs, drainage projects, irrigation enterprises and maintenance of and improvement and development of the waterways. This work forwards the cause of conservation to a wonderful degree because it supplies the fundamental data essential in its wise planning.

Another investigation by this branch has for its object the determination of the amount of material removed annually from the earth surface, as dissolved or suspended matter. It has been found that solid matter in solution is removed at the rate of 87 tons per square mile during each year, while 166 tons per square mile of suspended matter is carried to the sea annually, or a total



(U.S. G. S. Cut)

Ideal (cross-section) view of stream gauging method and apparatus.

loss of 253 tons per square mile per year. Surely no comment is necessary as to the importance of this to the farmer or to the engineer attempting to maintain a navigable waterway.

As a part of this study, water from lakes and rivers is analyzed. It is determined if the fluid be fit or not fit for drinking—for use in steam boilers or in manufacturing various commodities or in the arid states for irrigation.

The pollution of streams by sulphite wood-pulp waste, by sawdust, by the refuse from beet sugar plants, dairies, and by sewage is studied from a scientific standpoint, and it is readily seen that there may be people to whom these questions are of vital importance. About 5,000 analyses have been made of samples from 180 lakes and rivers.

A third line of activity in this branch is its investigation of underground waters. With the full use of the scant surface

(*U.S. G. S. Photo*)

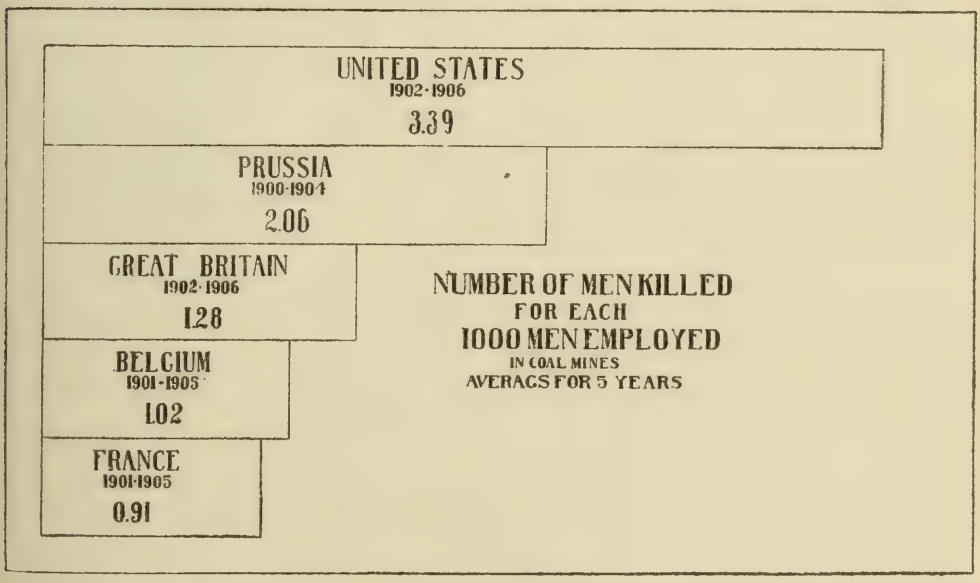
Gauging shallow stream which is too swift to wade.

waters in the arid states and their deterioration in quality through pollution by sewage or industrial wastes in the humid states, attention is turned to the less obvious supply beneath the surface. The quantity and quality of this, its accessibility and areas in which it exists, are the objects of careful study.

All the varied information that results from these studies is gathered and put into such form that anyone particularly interested may obtain it—free of cost and in such shape that he may read as he "runs" on his daily routine or special journey. All these facts are of immediate import in the development of that great natural resource Water—a subject full of meaning to the inhabitant of the desert wastes—the flooded stream valleys or the fever-breeding swamps of the lowlands.

TECHNOLOGIC WORK OF THE SURVEY.

The Technologic Branch, the youngest member of the Survey, which was created April 2, 1907, is charged with three important investigations—investigations of the causes of mine disasters with



the purpose of decreasing the death rate in the mines; investigation of the fuel resources of the country with special reference to the fuels used by the Government itself; and investigation of the structural materials used by the Government.

The principal work of the branch is carried on at Pittsburg, Pennsylvania, where a thoroughly equipped testing station has

been established. The experiments into the causes of mine disasters are perhaps the most important from a humanitarian standpoint. The work was started in July, 1908, with an appropriation of $150,000.

Statistics gathered by the Geological Survey show 2,061 miners killed and 4,800 injured in the coal mines in 1906, and 3,125 killed and 5,800 injured in 1907. The death rate for 1907 was 4.86 for every 1,000 men employed. The European coal producing countries show a death rate in mining of between one and two in every 1,000 employed. In other words, for every miner killed in European coal mines from two to four are killed in the United States. Since 1889, more than 30,000 miners have been killed in the United States.

The lower rate of fatalities in European countries is due to the establishment by the governments of testing stations for the investigation of problems relating to safety in mining, including the use of explosives. At the Pittsburg station, the principal work consists of testing explosives to determine their safety when fired in the presence of explosive gas or coal dust, and much progress has already been made along this line.

The tests are conducted in a steel cylinder 100 feet long and 6 feet in diameter. The cylinder provided with escape valves is filled with fire damp or coal dust, and the explosive is fired into the gas or dust by means of electricity from an observation house 60 feet away.

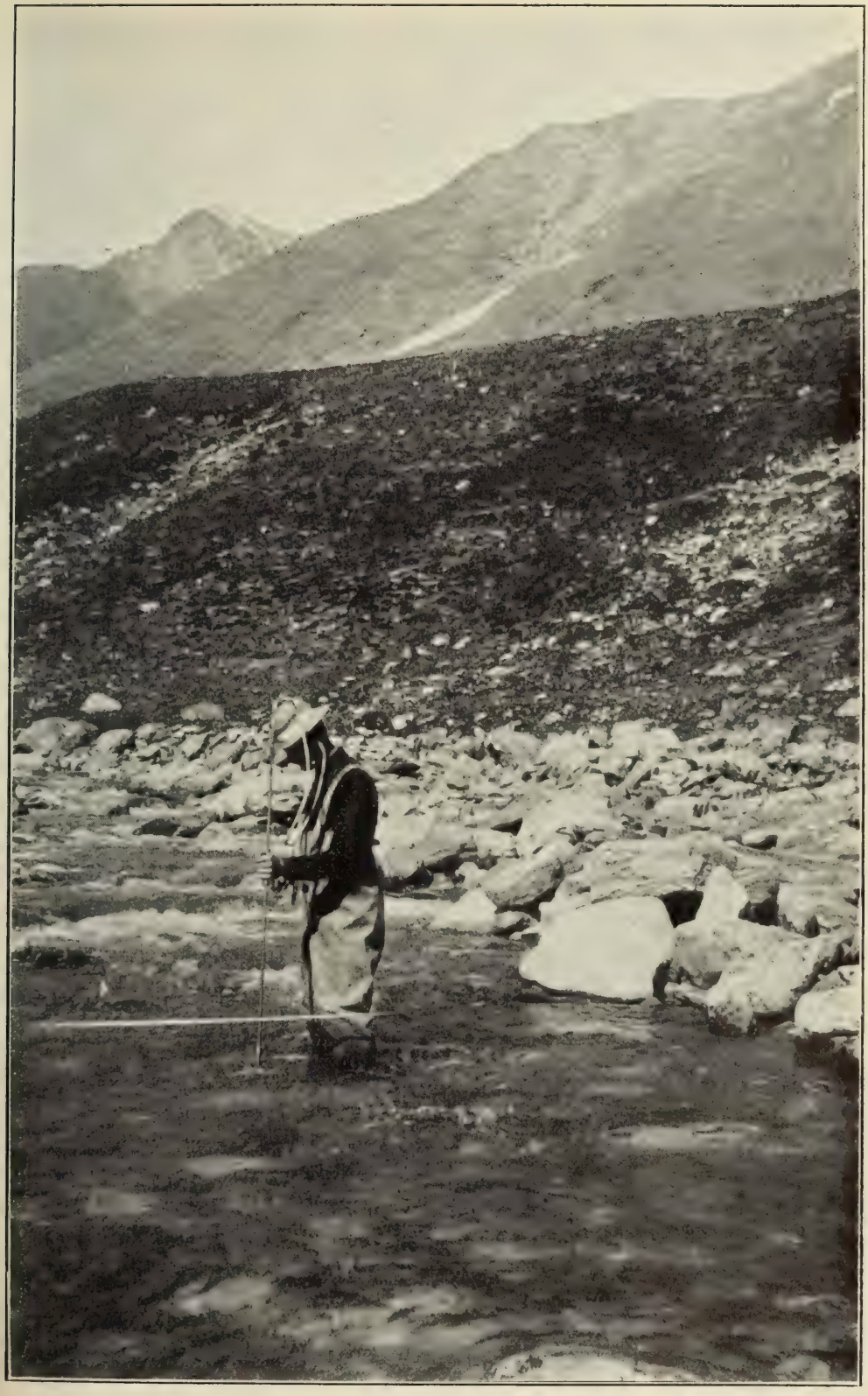
In addition to this the station is fully equipped with other apparatus designed for testing explosives. The ballistic pendulum used for this purpose, illustrated herewith, consists of a very heavy mortar suspended from a knife edge. The explosive, whose strength is to be tested, is placed on the small mortar face to face with a large mortar; the discharge of the explosive gives a swing to the large mortar which is measured. This, in a way, standardizes the strength of various explosives.

This part of the station is working twenty-four hours every day with three shifts of men, in order that certain badly needed information concerning explosives may be obtained as early as possible.

It is the purpose of the Government to continue the testing of explosives until certain of them can be recommended to the various State mining bureaus, coal mine owners, and miners as being reasonably safe.

(*U.S. G. S. Photo*)

Gauging station on a large river.



(U. S. G. S. Photo)

Gauging a shallow stream.

SEVERAL RESCUE STATIONS.

At Pittsburg is located the principal mine rescue station in the country, being in the center of the greatest coal field in the world. A second station has been established at Urbana, Illinois, in connection with the University of Illinois. Other stations will probably be established at or near other mining centers.

Government mining engineers thoroughly trained in the use of the rescue apparatus have been assigned to the stations already established, and are ready at a moment's notice to go to any disaster in their district. When an explosion occurs in a coal mine, the re-establishing of the ventilating current is often delayed several hours and many lives apparently have been lost because rescuers are unable to advance beyond the point where the mine is ventilated to find the persons who have suffered no physical violence from the explosion, but who are slowly dying from the inhalation of poisonous and non-life supporting gases. With a properly equipped rescue corps wearing oxygen helmets many lives may be saved if the corps can reach the mine within two or four hours after the explosion. Such is the record at mines in foreign countries which are equipped with similar rescue apparatus, and in several mines of the United States where the apparatus has been brought into action within a few hours after the explosion. A number of coal operating companies have realized the advantages of such safety appliances and have installed them at some place convenient to their mines.

The stations are fitted up with air-tight rooms where gas can be generated. The coal mining companies are invited to send picked men to these stations where they will be trained by the government experts in the use of the oxygen helmets. It is not the purpose of the Government to engage in general rescue work but rather to demonstrate this apparatus until such time as the mining companies have thoroughly trained rescue crews at their mines.

Mine rescue apparatus of the compressed oxygen type offers means by which a person wearing it may breath naturally with little inconvenience for a continuous period of two or three hours when surrounded by deadly gases, irritating fumes, smoke or other irrespirable gases and enables a certain amount of work to be done while wearing the apparatus.

The essential function of such an appliance is to furnish an atmosphere of oxygen and nitrogen in the proportion of about one of oxygen to four of nitrogen and a minimum amount of carbonic acid gas.

FUELS AND STRUCTURAL MATERIALS.

Attention has frequently been called to the profligate manner in which the people of the United States have used, and are continuing to use, the resources with which nature has so richly endowed them. For several years past the Geological Survey has been studying the causes of and means to prevent unnecessary waste, with particular reference to fuel and structural materials.

The mineral production of the United States for 1907 exceeded two billion dollars and contributed 65 per cent of the total freight traffic of the country.

The waste in the mining, treatment, and use of mineral substances during that year was equivalent to one million dollars a day.

No accurate estimate can be made as to the total unnecessary losses in connection with the use of coal for different purposes, but lines of urgently needed investigation and inquiry are indicated by the facts that in the vast majority of the power plants of the country less than 10 per cent. of the heat units in the coal are converted into actual work, and that in lighting plants, not more than one-seventh of 1 per cent of the heat value of the coal is converted into electric light.

The investigations which are now being conducted at the Pittsburg plant are directed toward the decrease of the great waste, not only in the mining but chiefly in the utilization of the coal. which the United States owns or purchases for its use. The results so far indicate that the Government, which purchases $10,000,000 worth of coal each year, and the public, who buy nearly $2,000,000,000 worth, may ultimately save from 5 to 10 per cent. on their fuel bills as a result of these investigations. If the economy reached but 5 per cent, this would mean a saving of half a million dollars to the Government and one hundred million dollars to the public.

As a result of the tests made, a plan has been perfected by the Government for the purchase of its coal on specifications and most of the departments are now so buying their fuel. Premiums are

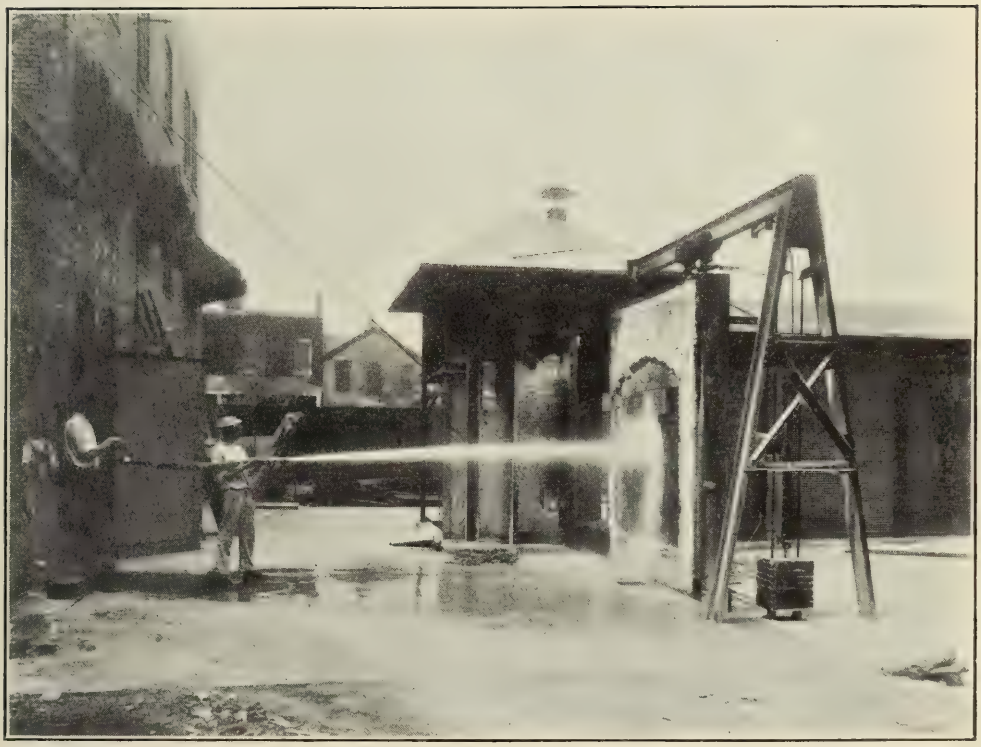
(*U.S. G. S. Photo*)

TESTING PLANT AT PITTSBURG.

Explosion Chamber. A huge iron tube into which various mixtures of gases or of dust with air are introduced and then exploded by firing.

(*U.S. G. S. Photo*)

Explosion Chamber. Same tube at time of an explosion. The columns of smoke escape through "manholes," which are left unfastened to prevent destruction of the chamber.



(*U.S. G. S. Photo*)

BUILDING MATERIAL TESTS

The material is carried on a steel frame and is heated to high temperature in the peaked building. The frame is then run out and the material wetted by a stream from hose. Changes are then noted.

paid for coal better than the standard and penalties are demanded for coal below the standard.

MAKING FUEL DO GREATER WORK.

The tests in the gas producer have shown that many fuels of such low grade as to be practically valueless for steam furnace purposes, including slack coal, bone coal, and lignite, may be economically converted into producer gas, and may thus generate sufficient power to render them of high commercial value. Coals as high as 45 per cent. ash, and lignites and peat high in moisture, have been successfully converted into producer gas, which has been used in operating gas engines. It has been estimated that on an average there was developed from each coal tested in the gas producer plant two and a half times the power developed when used in the ordinary steam boiler plant. It was found that the low-grade lignites of North Dakota developed as much power when converted into producer gas as did the best West Virginia bituminous coals when utilized under the steam boiler. In this way lignite beds under lying from 20,000,000 to 30,000,000 acres of public lands, supposed to have little or no commercial value, are shown to have a large value for power development.

In the fuel testing plant, with the best Kanawha Valley coal, the steam plant produced 0.28 horse power per pound of coal per hour, and the gas producer 0.96 horse power, or 3.34 times the efficiency for the producer gas plant over the steam plant. The remarkable feature in these tests was the comparison between the Kanawha Valley coal under the steam boiler and the lignite in the producer gas plant. The former under the boiler produced 0.28 horse power per hour, while the lignite produced 0.30 horse power per hour when operated in the producer gas plant or 1.04 times the power of the best steam coal burned in a boiler furnace.

Another important feature in conserving the coal supply is found in the manufacture of briquettes. These are composed of waste bituminous or anthracite coal mixed with 6 or 7 per cent of. gas pitch, the whole pressed into cakes or briquettes by machinery. Briquettes have been used in foreign countries for many years with much success.

At the Pittsburg plant, a German machine for briquetting lignites without binders has been installed. If these tests are

successful, the west will have an important supply of domestic fuel which it has never looked for.

The investigations into smoke abatement have indicated clearly that each type of coal may be burned practically smokelessly in some form of furnace or with some arrangement of mechanical stoker, draft, etc. The fuel testing plant at Pittsburg, operating from 200 to 600 H. P., at a time, does not make any objectional smoke.

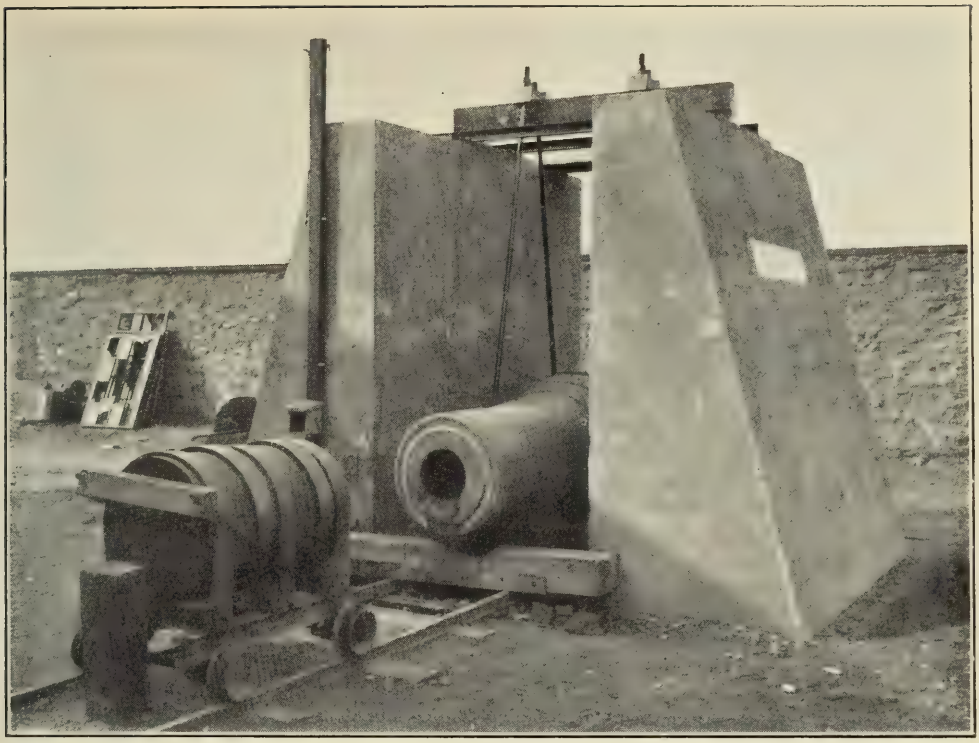
The washing of coals has demonstrated the fact that many coals in the Rocky Mountain region, which are too high in ash and sulphur for economic use under the steam boiler, or for coking, may be rendered of commercial value by proper treatment in the washery The coking tests have also demonstrated that by proper methods of preparation, etc., many of these coals which were supposed to be of no economic value for coking purposes may be rendered so by proper washery treatment.

To Curtail Fire Losses.

As part of the investigations into the structural materials of the country, statistics have been collected which show that during 1907 the building fire losses in the United States reached the enormous total of $215,084,709. This figure does not represent the excess premiums from insurance paid, cost of fire departments, private fire protection, etc. The total cost of fires in the United States in 1907 amounted to $456,486,151 or a *per capita* loss of $5.34. If we had the conditions that obtain in Europe our total cost would have been less than one hundred million dollars.

The average yearly fire loss from 1897 to 1906, inclusive, was $2.70 *per capita*, while in six of the leading countries of Europe the average *per capita* fire loss in 1906 was only 33 cents.

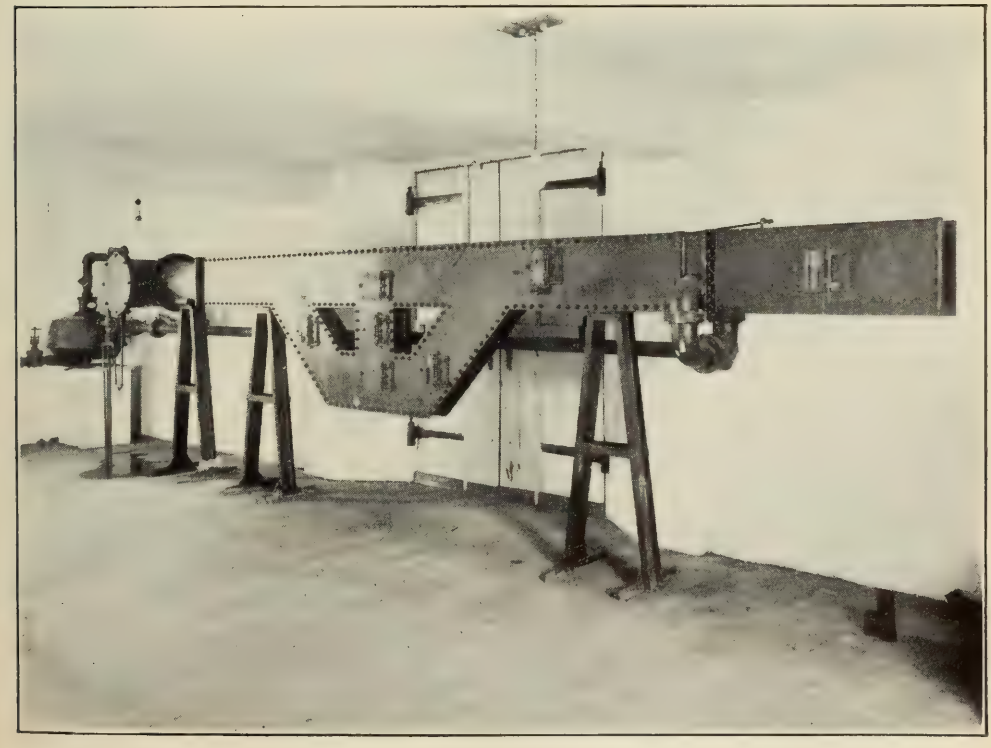
The census statistics for the single year of 1900 show a total of 6,772 deaths which resulted from burns and scalds in the United States. There is every reason to believe that this large loss of life and property could have been largely prevented by the proper construction of dwellings, factories, and office buildings. Practically fire-proof construction, especially in the cities, costs but little in excess of the more combustible style of buildings, and is economical in the end. The study of structural materials by the Survey is conducted primarily in behalf of the United States Govern-



(U.S. G. S. Photo)

PITTSBURG PLANT.

Apparatus for testing force of various explosives used in blasting.



(U.S. G. S. Photo)

Apparatus for testing safety lamps, which are placed inside the several doors shown and inflammable gas is introduced through the pipe connections.

Interior of air-tight room where miners are trained in rescue work. Room is fitted up to represent difficulties to be met with in mine where disaster has taken place. Two of the rescuers are carrying asphyxiated man, while third is giving oxygen treatment to another.

(*U.S. G. S. Photo*)

TECHNICAL BRANCH.

The helmet apparatus worn by Rescue Corps when entering a coal mine.

ment, which owns buildings valued at more than $1,000,000,000 and which is expending $30,000,000 annually for new buildings. But it is also of great value to the people who are expending each year for building and construction work approximately $1,000,000,000. The Government does not insure against loss by fire and the study of structural materials is costing the Government only a small fraction of what would be paid to insurance companies in premiums.

Reconnaissance survey has been made of the supply of constituent materials near several building centers and locations for engineering construction, as per request from the Supervising Architect, Corps of Engineers, United States Army, United States Reclamation Service, and other branches of the Government service. This survey indicates clearly where the Government may find these materials most convenient and economically available for the construction of public buildings and engineering works.

In the preceding pages it has been the endeavour to indicate without special reference the close interrelation of the various branches of work of the Geological Survey. It had been shown that the topographic base map is essential to nearly all the phases of the work. The geological, mineral resources, classification of lands, technical investigations, water resources and special investigations are all so interrelated that to discontinue any of them would mean a serious handicap to the others.

For each line of investigation effort is made to get the results into the hands of the public by means of reports, graphic tables and maps at the earliest possible moment.

In the progress of the field work of the various branches the men are constantly required to meet changes and unexpected conditions, and resourcefulness is one of the attributes developed by service in the corps. In the course of its 30 years the Survey has been called upon to supply information and plans of work for a great variety of purposes.

Its members have been sent to explore vast wildernesses, barren deserts, and huge mountain ranges; to map and report upon areas rich in farm productions and dotted with houses, or to visit restless mining camps far from railways, and on questions of fact, its experts are sometimes required to furnish data in important disputes. In all stages of civilization, or lack of it, the parties will be found each labouring to accomplish the particular task before it.

The wagons may be encountered on land but the occupants prepared to "take to the water" on short notice Its men may be discovered gathered around camp fires in far off corners of our land—or with tents pitched close to the seeping water of a desert spring. On his journeys a member may encounter interesting inhabitants, some of which are but the ghosts of the past, but the purpose which he is striving to accomplish, whatever it is or wherever he be, is primarily on his mind.

The success of the organization is due to its willingness to attack any task set it by the people as represented in Congress, and to the thought, energy and enthusiasm displayed in the undertaking of problems that they be completely solved along the lines of human benefit, science and truth.

CRITERIA OF DOWNWARD SULPHIDE ENRICHMENT. (*)

By F. L. RANSOME, Washington, D. C.

(Annual Meeting, Toronto, 1910.)

INTRODUCTION.

Since 1899, when S. F. Emmons, C. R. Van Hise and W. H. Weed, bringing together and developing what had hitherto existed only as scattered suggestions, formulated the principles of secondary sulphide enrichment, the great importance of the process has received general recognition, and such enrichment has been widely appealed to in explanation of the fact that many ore deposits, especially lodes, have a rich upper portion and deteriorate with increasing depth. With the details of the process itself this paper is not primarily concerned. It aims rather at a critical examination of the various lines of evidence by means of which the question whether or not the process has been operative in any given case may be answered. It is the outcome of a personal need, with which other students will perhaps sympathize, for some concise and orderly arrangement and evaluation of the criteria available for a decision. If the attempt is helpful in clarifying our ideas or serves but as a mere skeletal form about which a more nearly perfect expression of truth may crystallize, it needs no apology for its comparatively small leaven of originality.

A summary of this kind, moreover, may suggest lines of observation that can be pursued by those actively engaged in mining, who in their opportunity to study an ore body day after day as development proceeds, have one distinct advantage over the geologist who ordinarily examines it at only one stage. The

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ability to see things accurately and honestly is a fundamental requisite to scientific research, and every man engaged in mining may, if he chooses, advance our knowledge of ore deposits by recording with discrimination what he observes and knows to be true.

GEOLOGICAL EVIDENCE.

All the criteria to be considered are in one sense geological; but it is proposed under the present head to discuss first the broader relations of the ore bodies to topography, general structure, and geologic history.

In a study of the ore deposits of a district the hypothesis of downward enrichment is likely to be first suggested by an observed relation of the present topographic surface to certain changes, common to a number of deposits, in the kind of ore with increase of depth. Thus we may have, as in many of the western copper deposits, leached ferruginous gossans under which are bodies of chalcocite ore grading downward into disseminated cupriferous pyrite; or, as in the Breckenridge district, Colorado, veins in which the characteristic ore of the upper levels is argentiferous galena, more or less altered to cerusite, while in the lower levels sphalerite and pyrite become increasingly abundant. It is not always easy to ascertain whether an observed downward change in character of the ore deposits of a given district is significantly related to the topographic surface. Determination of the question requires considerable mining development. Moreover, the relation between vertical ore sequences and the topographic surface, even where topography and changes in ore are genetically connected, is likely to be so irregular that the geologist may remain in some doubt as to whether the apparent relation has any real significance. The answer to this question will in general be clearer the stronger the surface relief.

If in a district of pronounced relief there is a recognizable correspondence between topography and successive ore zones as found by vertical development, the next important step in the investigation appears to be the determination, if possible, of the general relation of the present topography to that in existence when the ore bodies, or the lean materials from which these have resulted, were deposited. Evidently if the first deposition took

place when the topography was similar to that now existent, the observed relations of ores to surface may be due to causes entirely independent of downward enrichment. On the other hand, if it can be shown that the original ore deposition long antedated the development of the present land forms, that many hundreds or thousands of feet of rock have been removed by erosion since the formation of the veins, then the observed relations of ores to surface becomes very strongly suggestive of downward enrichment. The operation of this process becomes demonstrable if it can be further shown that the original ore deposition and the general position and configuration of the present surface have not been both determined by some antecedent factor, such as, for example, the occurrence of beds of quartzite particularly favourable for the deposition of certain kinds of ore and especially resistant to erosion. Other less simple conditions are conceivable that might determine ore deposition within a zone having a certain vertical range and which might long afterward result in bringing the topographic surface into general coincidence with this zone. Here, as in most other geological problems, extreme or ideal conditions will seldom confront the investigator; he will be called upon to draw conclusions from facts that are more or less obscure and from evidence that rarely points unwaveringly to the truth.

Another group of criteria that may be considered here are those derivable from the general relations of a zone of sulphide enrichment to the overlying zone of oxidation. The mere presence of a deep, oxidized and leached cap, suggests that enrichment will be found below. Where such a gossan is directly underlain by an ore body that grades downward into low-grade material the geologic evidence of enrichment is complete.

As Weed* has pointed out, "enrichment is largely dependent upon the presence of marcasite, pyrite or some other form of iron sulphide in the primary ore, since lixiviation depends upon the iron sulphates and precipitation is mainly effected by the unaltered sulphides." It appears highly probably that this is not the only type but that some enrichment may take place in deposits nearly free from pyrite through reactions not involving large quantities of iron sulphates. Yet the best known and most authentic examples

*Enrichment of gold and silver veins. Trans. Amer. Inst. Mng. Eng. Vol. XXX, 1901, p. 439.

of the process are those in pyritic deposits and consequently we may regard leached gossans containing abundant limonite or hematite as useful geologic indications of enrichment below.

If this process has been effective the sulphide ores below should have certain definite relations to the oxidized material above. The vertical succession of sulphides below the limit of oxidation should be in general the same in each deposit. Moreover, each variety of sulphide ore should under normal conditions be at approximately the same distance below the oxidized zone or should occur at depths whose variation from the normal is explainable by special circumstances favouring or opposing the downward penetration of solutions from the leached portion of the deposit.

In arid regions were the groundwater lies deep and has probably undergone fluctuations in level both oxidation and enrichment may exhibit great irregularity in vertical range and yet maintain an obvious close relationship. Thus at Bisbee, where much of the oxidation may date from pre-Cretaceous time and where the groundwater has probably undergone several changes in level, oxidation has extended to the extraordinary depth of at least 1400 feet, while sulphide ores are found within 200 feet of the surface. The enrichment of these residual masses, however, has proceeded in general from their peripheries inward or from later fissures outward and is just as clearly the result of solutions emanating from the oxidized parts of the ore bodies as is the case in the well-known deposits at Ducktown, Tennessee, where the enriched layer is thin and conforms in general to a shallow, stable and fairly uniform groundwater-level.

MINERALOGICAL CRITERIA.

Obviously if we were able to conclude that certain metallic sulphides or certain gangue minerals associated with sulphides in unoxidized ores are formed only at low temperature by downward-moving solutions we should have a ready means of distinguishing those deposits in which descending enrichment has taken place. Unfortunately, however, most of the minerals found in ore deposits appear to be capable of forming under varied conditions of environment, of temperature and of depth or pressure.

Thus in the useful lists prepared by Lindgren* and by W. H. Emmons† there are very few minerals outside of those characteristic of the zone of oxidation, that so far as we know are rigidly limited to any one division of the whole vertical range of formation exhibited by the minerals associated in ore deposits. In Lindgren's list covellite (Cu S) is the only sulphide peculiar to the lower groundwater zone or zone of sulphide enrichment. Chalcocite (Cu_2S) is given as characteristic of this zone but is doubtfully included also in the "middle and upper vein zone" and in the "deeper vein zone." Stephanite (Ag_5SbS_4) and polybasite (Ag_9SbS_6) are both given as occurring in the zone of sulphide enrichment, but are doubtfully listed also in the "middle and upper vein zone." Among the gangue minerals, kaolin is recognized only in the zone of sulphide enrichment and in the oxidized zone. In Emmons' table the minerals occurring in the zone of sulphide enrichment and in the oxidized zone are not distinguished. He notes chalcocite not only as occurring in "deposits of moderate and shallow depth" but also in "deposits of the deep vein zone." In his table no sulphide appears as definitely diagnostic of the zone of downward sulphide enrichment. In another place W. H. Emmons,‡ following L. C. Graton, refers to the chalcocite of the Virgilina district in Virginia and North Carolina as original, and remarks that in that locality alone, so far as he is aware, has primary chalcocite been found. But inasmuch as Weed¶ had previously shown convincingly that some at least of the Virgilina chalcocite is secondary this supposed exception to the general occurrence of the mineral as a result of sulphide enrichment has remained a little doubtful.

Since this paper was read before the Institute, Mr. F. B. Laney has presented before the Geological Society of Washington** the results of a microscopical study of the Virgilina ores. He finds that chalcocite occurs in them partly as veinlets of secondary

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*The relation of ore-deposition to physical conditions. Economic Geology, vol. II, 1907, pp. 105-127.

† A genetic classification of minerals. Economic Geology, vol. III, 1908, pp. 611-627.

‡ Some regionally metamorphosed ore deposits and the so-called segregated veins. Economic Geology, vol. IV, 1909, p. 772.

¶ Enrichment of gold and silver veins. Trans. Amer. Min. Eng., vol. XXX, 1901, p. 433, fig. 2.

** Meeting of March, 1910.

origin traversing older bornite and partly as intimate intergrowths with the bornite. These intergrowths prove that a part of the chalcocite is as old as the bornite. The intergrown bornite and chalcocite occur in the deepest workings, down to about 500 feet, and there is no direct evidence that they have resulted from the alteration of chalcoyprite. There is, however, a possibility that both minerals are secondary. One ground for considering all of the chalcocite at Virgilina as an original constituent of the veins appears to be the fact that it is enclosed in solid coarsely crystalline quartz supposedly impervious to downward-moving solutions. The validity of this reasoning will be considered later.

Of great interest in this connection is the occurrence of chalcocite in the Paleozoic and Mesozoic sandstones of New Mexico, Colorado, Utah and adjacent states*. Lindgren and Graton, in a report on the ore deposits of New Mexico now in press, discuss the genesis of these deposits and, after showing that they are not significantly associated with igneous rocks or with deep fissuring, reach the conclusion that the chalcocite associated in some places with pyrite, chalcopyrite and bornite, has been deposited contemporaneously with the other sulphides and is not a product of enrichment. They believe, however, that the deposits are due to concentration by waters of atmospheric origin charged with sulphates and chlorides, deposition being effected by reduction brought about in part by organic material. Accordingly this chalcocite while not, strictly speaking, the result of downward sulphide enrichment has been formed under analogous conditions as regards temperature, pressure, and kind of solution. A similar explanation probably applies to the occurrence of disseminated chalcocite in the lower Cretaceous Glance conglomerate at Bisbee, the copper in the conglomerate having been derived from the great deposits in the Paleozoic limestones and concentrated by meteoric waters.

So far as our present knowledge of its occurrence goes, I believe that we are justified in regarding chalcocite as a mineral very rarely if ever formed except under the conditions of downward sulphide enrichment or by vadose sulphate solutions. Of course any such generalization is subject to be overturned by new evidence, but the burden of proof appears to rest at present upon those

*See Emmons, S.F. Copper in the red beds of the Colorado Plateau region. Bull. U.S. Geol. Survey, No. 260, 1905, pp. 221-232.

who support the view that chalcocite can be deposited simultaneously with quartz and pyrite or other sulphides characteristic of unmodified or primary veins. Outside of the two copper sulphides covellite and chalcocite there are no minerals that, so far as we know at present, are peculiarly the products of sulphide enrichment, although there are a number, the presence of one or more of which in any ore body, is distinctly suggestive of that process. Among these may be mentioned the silver minerals argentite, proustite, pyrargyrite, stephanite, polybasite and probably a goodly number of the more complex sulpharsenites and sulphantimonites. It is quite possible that further study of ore deposits may result in showing that some of these minerals, especially proustite, are fully as characteristic of downward enrichment as is chalcocite.

Marcasite is listed by Lindrgen as a mineral of the "middle and upper vein zone", while Emmons places it not only in these zones but also among the secondary minerals in the zone of oxide and sulphide enrichment. The researches of E. T. Allen* and his colleagues of the Geophysical Laboratory of the Carnegie Institution have shown that, while pyrite is a stable form at all except possibly very high temperatures, marcasite is a form taken under certain conditions by the disulphide of iron at low temperatures, the inversion point between the two, under the conditions of the experiments, being in the neighbourhood of 400° C. This indicates that if during the process of sulphide enrichment it is possible for the disulphide of iron to separate from solution it may take the form of marcasite rather than pyrite. Consequently the presence of marcasite in an ore deposit, although this mineral may in some cases be an original constituent in veins formed under moderate pressure and temperature, affords a strong suggestion of enrichment by descending solutions.

There is considerable evidence to show that bornite and chalcopyrite may in some cases be secondary with reference to associated pyrite, but as both minerals are certainly primary in many contact-metamorphic deposits, their mere presence in an ore body is of no value as a criterion of enrichment. Tetrahedrite, enargite and numerous other sulpharsenites and sulphantimonites are also of doubtful utility as criteria in our present stage of knowledge.

* Oral communication.

Kaolin, according to Lindgren,* occurs only in the oxidized zone and in the zone of sulphide enrichment. If this be true, the association of kaolinite with metallic sulphides constitutes a most useful criterion for the recognition of downward sulphide enrichment. In the Silverton district of the San Juan region of Colorado, however, kaolinite appears to have formed contemporanously with abundant, well-crystallized pyrite and with bournonite, enargite, guitermanite ($3\ PbS.\ As_2S_3$) and zunyite ($[Al(OH, F, Cl)_2]_6\ Al_2Si_3O_{12}$), on Anvil Mountain near Silverton. It occurs also in the same district in the Yankee Girl and near-by mines, associated with pyrite, chalcopyrite, bornite and stromeyerite. In a report† on the Silverton district published in 1901 the bonanzas of the Yankee Girl and other mines near Red Mountain were ascribed to downward enrichment but a part of the kaolinite was supposed to be of hydrothermal origin. I am not at present inclined to adhere strongly of the latter view, but recognize the possibility that the kaolinite may have been formed from sericite by acid solutions descending from an overlying zone of oxidation. The occurrence of kaolinite with alunite, quartz, pyrite, famatinite, bismuthinite, gold tellurides and native gold at Goldfield, Nevada, is rather more difficult to account for by the hypothesis of ordinary downward sulphide enichment, as has been shown in another place.‡ The hypothesis offered in explanation of the origin of the Goldfield ores, however, namely that of simultaneous solfatarism and oxidation, has so much in common with the process of downward sulphide enrichment that this exceptional occurrence of kaolinite does not conflict seriously with the view that the mineral is very rarely formed except in the zone of enrichment.

The very common gangue mineral quartz is known to form under a wide range of conditions from those of ordinary atmospheric pressure and temperatures to those under which granitic rocks have solidified. It is true that Mugge,** following up

* Ore-deposition and physical conditions. Economic Geology, vol. II, 1907, p. 120.

† Ransome, F.L. Economic Geology of the Silverton quadrangle, Colo. Bull. U.S. Geol. Snrvey, No. 182.

‡ Ransome, F. L. Geology and ore deposits of Goldfield, Nevada. Prof. Paper No. 66, U.S. States Geol. Survey, 1909, pp. 192-193.

** Ueber die Zustands anderung des Quarzes bei 570°. Neues Jahrbuch fur Min. etc., Festband, 1907, pp. 181-196.

Le Chatelier's discovery that quartz undergoes an abrupt change of volume at 570°., has shown that quartz at that temperature inverts to a second crystallographic form, distinguished as *B*-quartz, and that consequently it is possible to determine by refined optical methods whether a given quartz crystal was originally formed above or below the inversion temperature. This, however, does not help us to distinguish between quartz formed under hydrothermal conditions and high pressure in veins, and quartz formed by secondary processes in the zones of sulphide enrichment and of oxidation. While silica deposited near the earth's surface often assumes the form of opal of chalcedony the occurrence of quartz in geodes and of crusts of quartz over oxidized ore (in the Globe district, Arizona, for example, chrysocolla and malachite occur encrusted with quartz and traversed by veinlets of the same mineral) shows that high pressure and temperature are not essential to the formation of this mineral. Consequently it does not appear safe to assume that because a given sulphide is enclosed in quartz the sulphide has remained unchanged since the vein was first filled. On the other hand, the contemporaneous deposition of metallic sulphides with chalcedony or opal may be assigned considerable weight as evidence that they are the result of downward enrichment or have been deposited very near the surface.

Calcite, barite and fluorite appear to have no definite significance as regards sulphide enrichment, being present in original deposits formed at great depth as well as in the zone of oxidation. In other words, calcite and fluorite are classed by Lindgren as persistent minerals and barite should probably be put in the same group.

Among the mineralogical criteria of enrichment should of course be included the pseudo morphous replacement of one mineral by another. That chalcocite can thus replace pyrite, chalcopyrite or bornite has been thoroughly well established by many independent observations. Where, as in the Miami-Inspiration ore zone at Globe, crystals of pyrite have been superficially altered to chalcocite while still retaining their crystallographic form, the evidence of enrichment is conclusive. The careful study of the mineralogical details of such indubitable cases of enrichment as those at Miami and Ray is likely to add much to our knowledge of mineralogical criteria for the recognition of the process.

Assurance that the process has actually been operative affords us a secure vantage ground for further deduction as regards deposits whose origin is less certainly known.

In the absence from any deposit in question of any one mineral known to be characteristic of sulphide enrichment, recourse must be had to the significance of an association of minerals, which, from our knowledge of their occurrence and paragenesis elsewhere, are more or less suggestive of enrichment. Evidence of this kind, however, is in our present stage of knowledge, inconclusive and must be weighed in connection with other criteria presently to be discussed.

Although in general we should expect minerals resulting from downward enrichment to be formed at lower temperatures than those found in unmodified veins yet it is possible that the solutions effecting enrichment may under some circumstances be warm or hot. In arid regions where the ground water lies deep and the precipitation is slight the solutions percolating through the oxidized zone are likely to be of concentrated character and if pyrite, marcasite or chalcopyrite is abundant and if the mass is porous the chemical changes involved in oxidation may be so energetic as to develop considerable heat. This possibility suggests an explanation of the formation of specularite instead of or in association with limonite in certain gossans of arid regions as at the old Dominion mine near Globe. As Gàgel and Stremme* have shown, the presence of salts in solution lowers the water tension and permits of the formation of hematite at low temperatures.

CHEMICAL CRITERIA.

Inasmuch as downward enrichment implies selective transfer and redeposition of material originally present in a deposit, the result of the process may be studied chemically as well as mineralogically. One difficulty, however, lies in the fact that enrichment produces not merely a vertical gradation from rich ore to lean ore but effects a special kind of gradation by the superposition of one process upon another. A series of assays or chemical analyses may show that an ore body decreases in tenour below a certain depth, but such sampling as a rule is of little

* Centralblatt f. Geologie, 1909, p. 472.

use in detecting the essential fact of superposition of processes, unless it can be shown also that the change in tenour has relations to certain mineral groupings, or to topography, ground-water-level, or zone of oxidation. It may be possible in future to recognize some characteristic chemical distinction between a vertical gradation due to enrichment and a vertical gradation due to physical and chemical conditions controlling original deposition. The nature of the difference, if any, is not at present apparent.

Since a deposit cannot ordinarily be enriched by consitituents not originally present in at least small quantity in the primary ore, comparison of chemical analyses of the enriched ore and the primary ore should throw some light on our problem. Unfortunately, however, it is rarely practicable to secure samples of ore that are entirely free from suspicion of having been to some degree affected by whatever enrichment is supposed to have taken place above. Evidence obtained in this way may, however, have value from its negative character. If, for example, certain veins characterized by an upper zone of rich gold tellurides are found to diminish in tenour downward and finally pass into pyritic material containing no trace of tellurium the gradation is probably one of original deposition and not of downward enrichment—I say *probably*, because there is a possibility that an enriched deposit may not have been originally of uniform character; downward enrichment may be superposed upon an ore deposit that had originally a rich upper portion.

Another mode in which chemical analyses or assays may be utilized is in attempting to calculate from the composition of enriched ore and of material representing as nearly as possible the supposed original deposit, the amount of erosion or the vertical range of oxidation necessary to effect the concentration exhibited by the ore body under investigation. Cases are conceivable in which it might be possible in this way to check the hypothesis of enrichment by reference to facts determinable from the general geology of the region. As a rule, however, the data will be insufficient to permit of this comparison.

Yet another way in which chemistry may aid in the detection of downward enrichment is in the study of wall-rock alteration. While much has been done in the study of metasomatic

processes in connection with original ore-deposition, there has been as yet no careful study made of the chemical and corresponding mineralogical changes induced in the already altered wall-rock by the generally descending solutions effective in sulphide enrichment. This line of investigation has its obvious difficulties and the instances where it can be successfully undertaken are undoubtedly rare. Nevertheless the possibility of pursuing it when opportunities arise may well be kept in mind. Mineralogically the superposed effect upon the wall-rock of solutions producing downward sulphide enrichment is likely to be indicated by the alteration of sericite to kaolinite and in some cases by the development of alunite and diaspore.

TEXTURAL CRITERIA.

Under the heading of textural criteria of enrichment may be grouped a number of conditions directly observable with the naked eye or by means of the microscope in thin sections or on polished surfaces of ore. Among these may be mentioned the occurrence of veinlets of rich ore in leaner material, the encrusting of fragments of low-grade ore by shells of high-grade ore, irregular metasomatic replacement of one mineral by another, and evidence of solution followed by deposition of fresh material. Where these relations can be asceratined they constitute some of the most reliable criteria for establishing the fact of enrichment. Yet they cannot be taken by themselves since it is well known that ore deposits are often complex structures and that movement and fissuring following an initial period of deposition may be succeeded by fresh accretions of ore from deep sources, such additional material having no relation whatever to the process of downward enrichment. Evidently, therefore, the purely textural evidence must be weighed in connection with the mineralogical character of the freshly deposited material and with the relation of such deposition to erosion and to an overlying zone of oxidation.

In this place also belongs consideration of the degree of permeability of an ore body to percolating solutions. Obviously a highly porous ore, whether this porosity be original or the result of fracturing, will be more susceptible to extensive enrichment than a compact impervious one. Imperviousness, however, is often more apparent than real and is at best a relative property.

Ordinarily vein quartz even when not visibly fractured may be readily permeated by solutions, as anyone knows who has tried to write upon a fragment with thin ink. Evidently time is an important factor here and in attempting to decide whether or not the material of a certain vein is so impervious as to rule out the possibility of enrichment some attention should be given to the age of the deposit and the length of time available for the enriching process to have gone on. These considerations appear to be particularly applicable, for example, to the Virgilina veins, which are possibly Paleozoic or pre-Cambrian and which consequently may have been exposed to the action of downward-moving solutions for vast periods. Moreover, in the stresses to which such ancient veins must have been from time to time subjected, it is highly probable that the quartz has been microscopically fractured and has at some periods been more porous than at present. Specimens of chalcocite ore from the Virgilina district show that some of the chalcocite has undergone alteration to malachite although solidly embedded in quartz apparently as impervious as that from the deeper workings. In the Miami-Inspiration ore-bodies of the Globe district, moreover, many of the specks of chalcocite are solidly embedded in the silicified schist and in the veinlets of quartz so that they have every appearance of being products of the earliest period of mineralization. Yet the evidence here is conclusive that these specks of chalcocite have resulted from the alteration of pyrite and chalcopryite and probably is most cases exactly fill the space once occupied by the parent mineral. All stages may be seen from pyrite thinly coated with chalcocite to solid chalcocite. The enrichment, however, appears to have been accompanied by some solutions and deposition of silica and perhaps by some migration of the chalcocite in solution. Study of siliceous deposits that have undergone chalcocitic enrichment tends to prescribe caution in the use of apparent or present imperviousness of an ore body as an argument against the possible efficiency of the process, which appears to be capable of producing important results under conditions permitting only capillary or subcapillary movement of solutions.

CONCLUSIONS.

The criteria for the recognition of downward sulphide enrichment may be grouped as (1) Geological, (2) Mineralogical, (3) Chemical and (4) Textural.

The geological evidence most indicative of downward enrichment is progressive impoverishment of all similar sulphide deposits in any district with increase of depth. Complete demonstration requires, however, that the change in character of the sulphides should show dependence upon a topography decidedly younger than that existing when the veins were originally formed. In other words, the change in the ores should be uniform in sequence or kind and should be dependent upon erosion and oxidation.

Among the mineralogical criteria, the presence of chalcocite or covellite is most nearly unequivocal. These minerals are not known to be deposited from thermal waters derived from great depth unless possibly some of the Virgilina chalcocite was so formed. Other minerals such as argentite, proustite, pyrargyrite, stephanite, polybasite and probably other complex sulpharsenites and sulphantimonites are suggestive of downward enrichment but their presence is not, so far as we know at present, proof of this process. Marcasite, as regards the problem in hand, has similar standing. Among the non-metallic minerals found in ore bodies kaolinite and alunite, although exceptionally they may be formed in the upper zone of hydrothermal activity, are generally significant of the work of descending waters. Quartz, calcite, barite and fluorite appear to be deposited by descending as well as ascending waters. Pseudomorphous replacement of one mineral by another may constitute a valuable criteria of enrichment but should be considered in connection with the possibility of a change in character of hydrothermal solutions rising from great depth.

Chemical criteria may reveal the fact of a progressive downward decrease in the tenour of an ore body but still fail as a rule to establish the essential characteristics of enrichment, namely a superposition of one process upon another. Chemistry may in future help us to recognize the action of enriching solutions by their effects upon the wall rocks. Chemical and mineralogical criteria obviously overlap in a very intimate way.

Textural criteria such as the encrusting or veining of one mineral by another, are likely to be of much value but should be weighed in connection with the mineralogical character of the freshly deposited constituents of the ore and with the relation of

such deposition to erosion and oxidation. The impermeability of an ore body is never absolute and in considering the possibility of downward enrichment attention should be given to the age of the deposit and to the length of time during which enrichment may have been operative. The argument that because a vein is now dense and apparently impervious it cannot have been enriched from above, is one to be used with caution.

NOTES ON RECENT DEVELOPMENTS IN ASBESTOS MINING IN QUEBEC.

By W. J. Woolsey, Thetford Mines, Que.

It is generally conceded that the asbestos industry is now better established than ever before, and with stable conditions of trade must, in the near future, greatly increase in volume. Financiers have shown more than ordinary confidence in asbestos mining, and the various propositions offering have been accepted only too readily, especially if vouched for by competent authorities. Some have very severely deprecated, with justice in some cases, this recent great optimism prevailing in regard to asbestos. On the other hand, however, it must be recognized that asbestos is coming into much more general use. The increased demand, therefore, coupled with the adequacy and eminent suitability of most of the Quebec mineral, seems a sufficient reply to any who may be unduly pessimistic.

The present prices for the various grades of asbestos are from five to fifteen per cent. lower than in 1907 and accordingly shipments have been less than in that year. The outlook for the coming year is for increased shipments and a gradual improvement in prices.

The decision on the part of the operators in the Black Lake and Thetford districts to establish an Asbestos Bureau to keep the public advised of any new uses for asbestos, and the development of asbestos properties the world over, should afford the very greatest assistance in the industry.

Geological Features.

The geology of the asbestos area has lately received considerable attention from the Canadian Department of Mines, and an effort is being made to work out fully the important features as rapidly as possible. During the past thirty years many papers

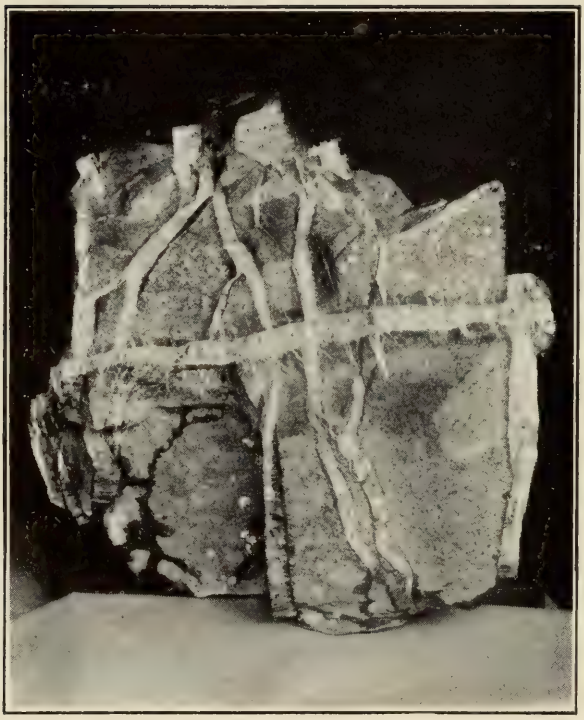


Photo by G. P. Merrill, Washington, D. C.

Block of Massive Serpentine, 30 x 30 x 27 in., traversed by veins of "Asbestos."

have been presented, and many theories advanced to explain the peculiarities observed in the district, having reference more especially to the questions of the true origin of the serpentines, the contrast between the growth of the chrysotile deposits throughout the world, and the origin and manner of growth of these fibres. Thus, valuable data bearing on these problems has been presented by Ells (*a*), Merrill (*b*), Low (*c*), Cirkel (*d*) and Dresser (*e*). The serpentines of the district are conceded to be of igneous origin derived principally from rock of the peridotite class, though there are frequent instances where pyroxene appears to have been an important original mineral. The formation of the chrysotile veins has been discussed by Merrill (*b*), who states, "Cavities are due to shrinkage and the vein filling to processes of crystallization, extending from either wall inward." The subject is also well treated by Low (*c*), who states that "The cracks were probably formed by shrinkage of the mass. . . . .The asbestos appears to the writer to have been deposited in the cracks under great pressure from superheated waters. . . . . masses and dykes have been intruded into the serpentines, and these probably account for the necessary pressure and heated waters to form the asbestos there."

It is the opinion of the writer that these theories account satisfactorily for the origin of the vein fractures, but that the growth of the chrysotile fibres extend from a given fracture *outward*, will be observed by referring to Plate A.

This plate is reproduced from a microphotograph of a specimen of asbestos-bearing serpentine from the Asbestos & Asbestic Company's mine at Danville, Quebec. A study of the specimen in this section indicates that the original rock was rich in olivine. The plate serves to illustrate the mode of development of chrysotile veins, and to show that the fissures were formed by the shrinkage of the cooling or charging mass and were filled under great pressure from the mineral solution from the adjacent walls. The mineral solution then crystallized, commencing at the centre and continuing until the walls of the fissure were reached.

(*a*) Bulletin on Asbestos, 1903, Geological Survey of Canada.
(*b*) Mining World, 1905.
(*c*) Geological Survey of Canada, 1906.
(*d*) Asbestos, its Occurrence, Exploitation and Uses, 1905.
(*e*) Journal of the C.M.I., Part of Vol. XII.

A good opportunity for studying the relation of some of the rocks containing and associated with the asbestos deposits may be found on the property of the Robertson Asbestos Mining Company, on Lot 16, Range IV, of the Township of Thetford. Here the surface outcrop measures 1,400 feet along the strike, north-east, by 600 feet in width, and consists of serpentine and a greenstone, probably diabase. These rocks lie between two beds of sedimentary rock, and all dip to the south-east at an angle of about 50°. Both contacts are well marked, an interesting feature of the upper one being those fragments of the sedimentary found in the igneous rocks.

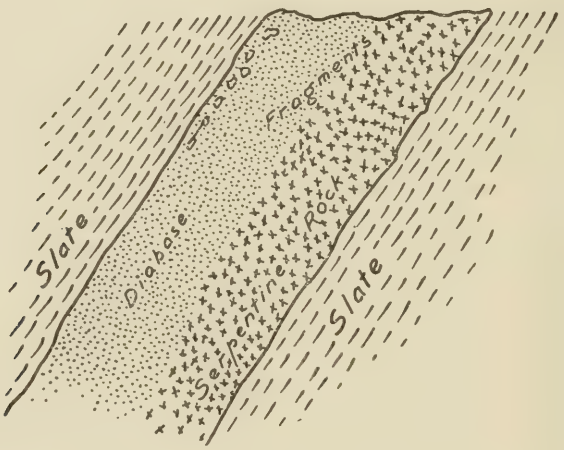


FIG. 1

Another significant feature shown in this diagram is that the serpentine is found along the lower or footwall side, while the diabase, which is a lighter rock, is near the hanging or upper wall.

Following out these observations, the purest serpentine should be found along the footwall. The writer has kept careful watch for change in the amount of asbestos, but has not found any noteworthy change towards either wall, in the amount of asbestos contained in the serpentine. The crystallization of serpentine to form chrysotile seems to be affected by other agencies than the quality of the serpentine alone. These might be pressure, heat or intrusion of dykes.

MINING METHODS.

The use of cable ways in asbestos mining is very general throughout the district. This method has been much criticised, but has, never-

theless proved very efficient in removing material from the pits. To it may also be largely ascribed the fact that the cost of mining has been maintained at the low rate of between twenty and thirty-five cents per ton of rock delivered and loaded on the cars. The variance in costs referred to is dependent on the extent of crushing and separation of rock material in the pits. All the mines are very completely equipped. This equipment usually comprises an air compressing plant and cable ways, provided with steam, air or electric hoists. In general, electric power is in use. It is especially well adapted, when continuous service can be maintained, for the operation of the mills, as well as for mine plant. It has also been successfully applied in the operation of drills, although an electric drill has yet to be devised in which the drawback of abnormal wear of certain parts shall be overcome.

Underground mining, although successfully carried on by Bell's Asbestos Company for the past four years, has not been adopted at other mines by reason of the increased cost. It is, meanwhile, interesting to note that the Bell's Asbestos Company is now installing a steam shovel plant. Mining by this method promises to be effective in the case of large workings and level bottom, of course, is desirable.

Milling Methods.

The question of efficiency of milling plant is one of paramount importance to those engaged in the production of asbestos fibre; but there is great divergence of opinion in the matter of mill design. There is, nevertheless, much truth in the contention that the processes necessary for producing the best results vary considerably according to the class of rock to be handled. In the opinion of the writer, however, much benefit would accrue if the designing of mill plants were standardised, so far as practicable, by the adoption in all plants of the several methods which experience has taught constitute the best practice. Thus, there are several mills in the district which possess distinctive and desirable features; but it is quite possible that none is in itself absolutely perfect in design. For example, rolls have proved very efficient, since they preserve the qualities of the fibre excellently well; at the same time these machines have not yet been installed in such a manner as to provide a maximum production in proportion to

the cost per ton. Again, the cyclone has proved invaluable, considered from the point of view of large production and low cost; but in determining the most desirable class of mill, the question of preserving the more valuable qualities of the fibre must, of course, be considered, and in the writer's opinion only low grade materials should go to the cyclone, the superior grades having been saved before this stage of milling shall have been reached. The accompanying flow sheet illustrates a mill design, which in the judgment of the writer would afford the best results in respect of efficiency and simplicity of operation.

A new machine has been designed by Edward Torrey and installed by the Asbestos & Asbestic Company, Danville, Que., to overcome the difficulties met with in the old style cyclone. A general idea of this machine may be obtained from Figure 2. It will be observed that in the new machine the reduction of the ore is effected more directly by impact than by pulverization, which is the principle of the old style cyclone, where the beaters revolve in opposite directions. It is claimed for the Torrey cyclone that the injury to the fibres occasioned by the old style cyclone is largely overcome, and that the operation of the new machine is less costly.

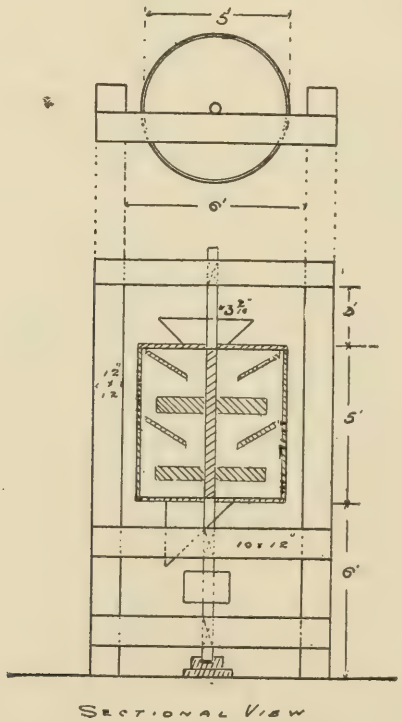
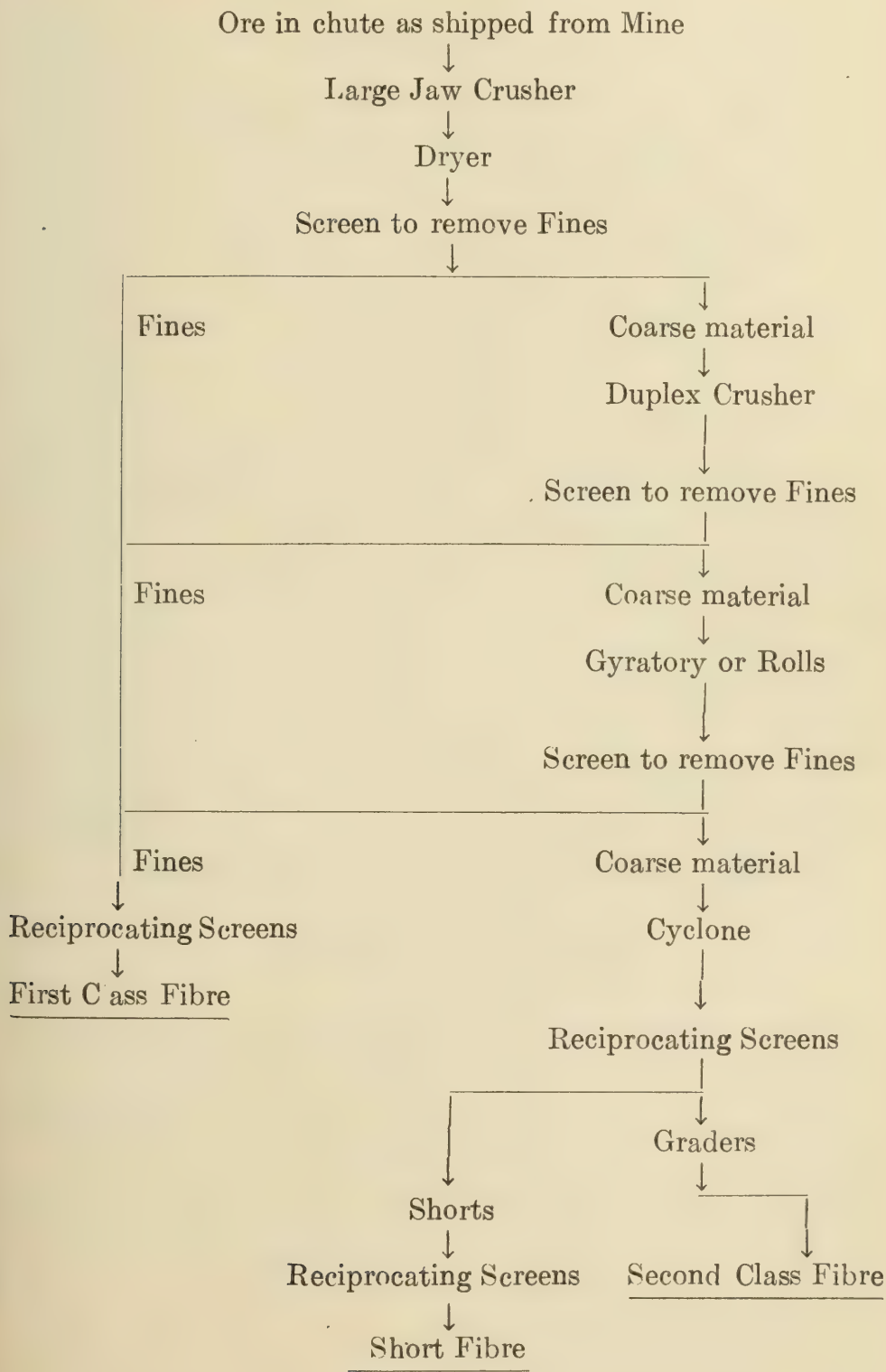


FIG. 2—Torrey Cyclone.

FLOW SHEET

SHOWING ASBESTOS TREATMENT THROUGH MILL



ON THE DISTRIBUTION OF ASBESTOS DEPOSITS IN THE EASTERN TOWNSHIPS OF QUEBEC.*

By JOHN A. DRESSER, Ottawa, Ont.

(Annual Meeting, Toronto, 1910.)

INTRODUCTION.

At the last meeting of this Institute a short paper was presented by the writer on the mode of occurrence of asbestos and chromite in the Eastern Townships of Quebec.†

In the interval further work has been done in the area, under the auspices of the Geological Survey, and certain relations have been ascertained between the productive and the unproductive parts of the serpentine belt in which these minerals occur. It is the purpose of this paper to show some of the geological relations of the serpentine belt and how they determine the distribution of the mineral deposits, and to apply the conclusions as an aid to prospecting for and estimating the value of further discoveries. For these purposes a brief review of the district is necessary.

REVIEW OF THE DISTRICT.

The part of the province of Quebec which lies south of the river St. Lawrence consists of a portion of the wide flat valley, or a plain bordering the St. Lawrence, and a hilly region extending from the plain to the boundary line between the Province

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[* Published by permission of the Director of the Geological Survey of Canada.

† "Mineral Deposits of the Serpentine Belt of Southern Quebec." Journal of the Canadian Mining Institute, Montreal, 1909.

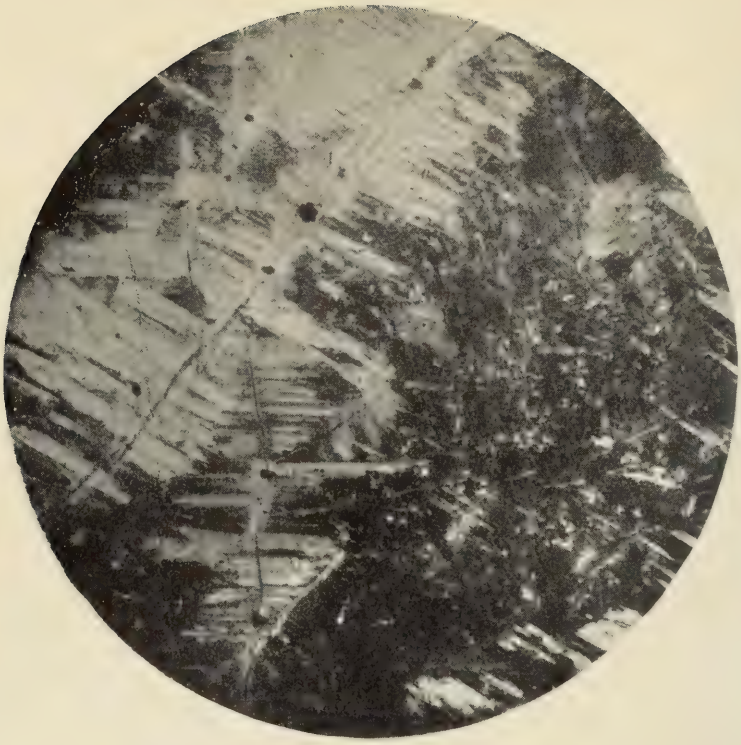

PLATE A. Micro-Photograph by N. R. Carmichael, M.A. School of Mining, Kingston.

PLATE B. Quarry of the King Bros'. Asbestos Mine, Thetford. Looking North-West.

of Quebec and the United States. The north eastern part of the hilly region in the Gaspe peninsula forms the Shickshock mountains; the southern part is generally known as the Eastern Townships. It is to the latter part of the region, and especially the portion between the St. Francis and Chaudière rivers, that this paper relates. These rivers are about 100 miles apart and from the area between them all the asbestos and chromite hitherto mined in Quebec has been obtained.

Series of parallel ridges running northeast and southwest are the principal features in the relief of the district. These are grouped into three principal ranges which are about twenty-five miles apart. One of these extends along the international boundary line near Lake Megantic, a second forms the hills of Capelton, Stoke and Weedon, passing near the city of Sherbrooke, and the third forms the hills of Broughton, Leeds and Ham and farther to the southward rises into Sutton mountain.

Sutton mountain, the highest point in the district, has an altitude of nearly 3100 feet. Several other hills rise 2500 feet or higher and there are considerable areas which are between 1500 feet and 2000 feet above sea level. The St. Lawrence plain varies in elevation from 100 to 400 feet.

The district is drained by the Chaudière, Beçancour, Nicolet, St. Francis and other rivers which cross the ranges of hills in a northwesterly direction and empty into the St. Lawrence. The tributaries of these rivers occupy the structural valleys between the ridges and generally run either in a northeasterly or southwesterly direction. They frequently empty into the larger rivers by falls or rapids and so furnish some of the principal water powers of the district, such as the falls of the Magog at Sherbrooke, or the Wattopekah at Windsor Mills.

The Quebec Central and the Grand Trunk railways give easy access to the greater part of the mining district. The principal mines are near the stations of Thetford Mines, Black Lake and East Broughton on the former, and Danville, on the latter line of railway.

Mineral Production.

Asbestos (chrysotile) is the most important mineral now mined in the province of Quebec. It comprises in value about half the

total mineral production of the province and in 1907, the latest date for which full returns are available, this district furnished 84% of the world's supply.

The mineral was discovered in Canada in the early days of the Geological Survey, about 1847, and thirty years later, 1877, it began to be commercially developed. Since that time there has been a constantly increasing production, as may be seen by reviewing the production* of one year in each decade since the industry was begun:—

Year	1878	production	50	tons	value.....	.....
"	1888	"	4,404	"	"	$255,007
"	1898	"	16,124	"	"	471,131
"	1908	"	66,548	"	"	2,555,361

The increase in production during the last decade has also been accompanied by a marked increase in price, To quote from the returns of production by Mr. McLeish, cited above, "The statistics indicate that during the past six years there has been only a slight increase in the quantity shipped as crude, although the average price has nearly doubled; while on the other hand the shipments of mill stock have increased over 125 per cent, with an increase of over 50 per cent in the average price per ton obtained."

To state this in concrete form, the average prices of crude asbestos and mill stock in 1903 were $115.46 and $19.79 respectively; in 1908, $200.04 and $29.84.

In consequence of the successful development of the industry in recent years, prospecting is active and the search for new productive areas is being vigorously prosecuted.

GEOLOGY OF THE DISTRICT.

General.—The central parts of the main ranges of hills are composed of igneous and sedimentary rocks of early age, in part at least pre-Cambrian. Flanking these are sediments of later Cambrian and Ordovician age, within which are isolated intrusions of granite which are believed to have been injected in Devonian time. On the southeast side of the Sutton and Leeds range of

* "The Production of Asbestos in Canada," 1907-8." By John McLeish, Chief of Division of Mineral Statistics, Department of Mines of Canada.

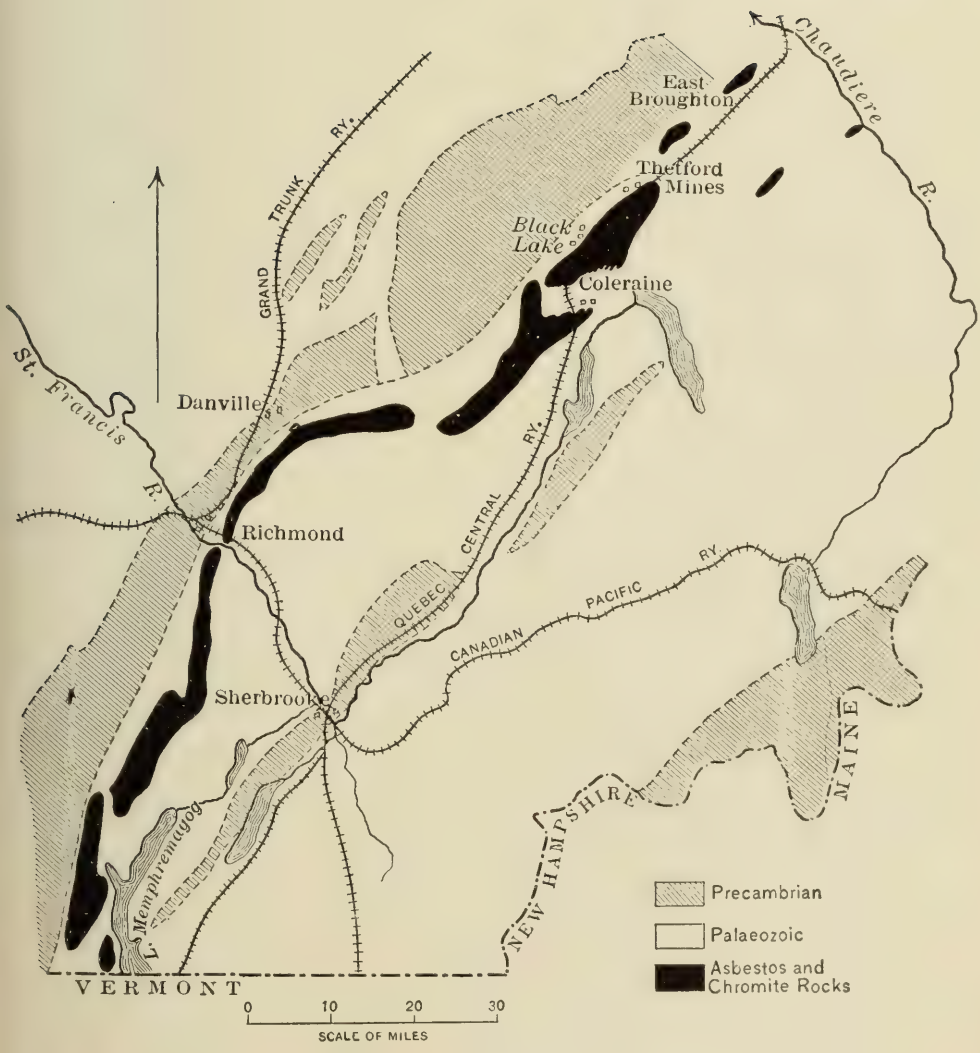
East Broughton
Thetford Mines
Black Lake
Coleraine
Chaudiere R.
GRAND TRUNK RY.
St. Francis R.
Danville
Richmond
CENTRAL QUEBEC RY.
CANADIAN PACIFIC RY.
Sherbrooke
L. Memphremagog
VERMONT
NEW HAMPSHIRE
MAINE
Precambrian
Palaeozoic
Asbestos and Chromite Rocks
0 10 20 30
SCALE OF MILES

Fig. I.

hills there is a series of basic intrusive rocks generally known as the Serpentine belt. It is in this that the asbestos and chromite deposits of the Eastern Townships are found.

Local.—The sedimentary rocks of the district are schists, slates, sandstones and quartzites of Cambrian and Ordovician age. They are highly altered rocks and much disturbed in position by folding and faulting. They have a general northeasterly strike and dips at high angles.

The igneous rocks in which the mineral deposits occur are all intrusive in the sediments. They have been injected at different times, although many of the different varieties of rock have been formed by differentiation from a single intrusion. At the contact of the intrusives with the sedimentary rocks large amounts of breccia have been formed, the sediments are baked and hardened, yet dykes are rare and there has not been any notable fracturing of the sediments. The intrusions have been gradual in their action.

The area occupied by igneous rocks is often and conveniently called the "serpentine belt" since serpentine is the rock which contains the principal mineral deposits. In the serpentine belt two phases of igneous rocks may be distinguished which differ in the values they contain, in the state of preservation, and perhaps also in age. They will be referred to as the Thetford phase and the Broughton phase from townships in which they are well developed. Their general characters are shown by a comparative view of the rocks which compose them.

Thetford Phase :—Serpentine, Peridotite, Pyroxenite, Gabbro, Diabase, Porphyrite, Granite, Aplite.

Broughton Phase :—Serpentine, Soapstone, Greenstone schists.

Thetford Phase:—The Thetford phase makes up the principal part of the serpentine belt. It includes the band of igneous rocks that extends southwesterly from Broughton mountain near the northeastern boundary of Thetford, through the townships of Thetford, Coleraine, Wolfertown, Garthby, South Ham, Wotton, Tingwick, Shipton and Cleveland. It probably also forms a large part of the serpentine belt further to the southwestward in the counties of Sherbrooke and Brome; but this area has not yet been

studied in detail. The country rock of the mines at Thetford, Black Lake and Danville belongs to this series.

The rocks of this phase are believed to have been formed by differentiation from a single magma. Serpentine is a metamorphic rock that has been derived by alteration from peridotite and in the hand specimen it is not easy to distinguish one from the other. They are both commonly called serpentine. Pyroxenite is a fairly distinct rock being often coarse grained. Gabbro, diabase and porphyrite are conveniently grouped under the name of diabase in the field, since they pass into one another by gradual transition and are not easily distinguished. Granite—in its fine grained acid phases aplite—is sometimes differentiated *in situ* from the other rocks, in others it has been intruded a little later showing the differentiation to have taken place previous to intrusion.

Broughton Phase.—The rocks of the Broughton phase form a narrow band that extends from range III of the township of Broughton southwesterly as far as the Robertson mine in Thetford. Through several ranges in Broughton it is confined to lot 13, but crosses the township towards the northwest as far as lot 2 in range XI. In Thetford it occurs principally in range V. Similar rocks also appear in ranges I, II and III of Tring, in or near lot 24; at the D'Israeli Asbestos Mine in Garthby range III lot 16, and in other isolated areas in Leeds and Ham.

This phase contains the mines and prospects of East Broughton and those in the vicinity of Robertson.

The rocks have not yet been examined in detail but they resemble the rocks of the Thetford phase in essential respects. The chief difference is in the state of preservation of the rocks although there may have been also difference in their original composition. Probably they originally contained more pyroxene In the Broughton phase there is little, if any, peridotite accompanying the serpentine, which indicates that the alteration to serpentine is nearly complete.

In the place of pyroxenite, which appears in the Thetford phase, there is its alteration product, soapstone, in the Broughton phase. The greenstone schists of Broughton probably had originally a composition similar to the diabase, or some closely related rock, in Thetford. Like the rocks of the Thetford phase they are doubtless differentiated from a single magma.

Granite has not been found in the Broughton phase except in an isolated occurence in range I, lot 24 of Tring, nor are any important bodies of chromite known in these rocks. These are the principal indications of different original composition in the two phases.

STRUCTURE OF THE IGNEOUS BODIES.

The rocks of the Broughton phase and portions of the Thetford phase occur in bands, which follow the dip and strike of the enclosing sediments, and thus form sills or intrusive sheets. Other portions of the Thetford phase occupy elliptical areas sometimes narrowly connected with one another which are uncovered portions of a batholith or thick laccolith. The rocks are arranged in the following order:—1st, serpentine; 2nd, pyroxenite; 3rd diabase,—in sheets, from the base upwards; in batholithic masses, from the centre outwards.

Where serpentine is in excess of the other rocks it sometimes extends to the top or outer edge of an intrusion, but the acid rocks whenever present are nearest the tops of sheets or the margins of other intrusions. Thus between the Danville Pinnacle and the St. Francis river, a distance of eight miles, the serpentine belt is in the form of a thick sheet dipping to the southeast at a high angle. Serpentine occurs along the northwest or footwall side, and diabase wherever present is on the southeast or upper side. The mines at Asbestos are in similar position with regard to the pyroxenite and diabase hills on the southeast and may be on the northeasterly extension of the sheet referred to above.

At the Robertson mine in the 16th lot of the range of Thetford serpentine forms the lower or northwestern half of a sheet dipping southeast at an angle of 50°, and schistose greenstone the upper or southeastern portion. Several exposures in Broughton show soapstone in the upper, and serpentine in the lower parts of a sheet.

This arrangement of the rocks agrees with the relative basicity, and density of the principal minerals, and with the order in which they generally crystallize.

DIAGRAMMATIC SECTION ACROSS THE SERPENTINE BELT

in range XIII, township of Cleveland, between lots 5 and 9

Scale : horizontal - 900 feet to ½ inch.
" vertical - 300 " " "

Fig. II.

Order of Crystallization.	Specific Gravity.	Rocks formed.
1. Olivine	3.32	Peridotite (Serpentine)
2. Pyroxene	3.20	Pyroxenite (Soapstone)
3. Feldspar	2.70	With pyroxene forms diabase, etc.

Olivine crystallizing first would, in the lighter portion of the magma remaining fluid, settle towards the bottom of the sheet, even if at a high dip, and form peridotite, which later has been altered to serpentine. Closely following olivine, pyroxene crystallized and likewise settled, forming pyroxenite. By later alteration this has become soapstone.

Where pyroxene and olivine became mixed together, through crystallizing simultaneously, they formed by alteration the harder variety of serpentine in the Thetford phase, or the talcose serpentine of the Broughton phase.

Where pyroxene was mixed with feldspar, which crystallized next in general order, diabase and the related rocks were formed. This separation would be more nearly complete, the more slowly the cooling took place.

Granite has been formed in sheets in only two cases as far as known. On lot 24, range 1 of Tring, it occurs as a differentiate at the top of the sheet. In the other instance, in the townships of Cleveland and Danville, it appears to have been injected later than the serpentine in which it occurs principally as dykes.

In the areas that are regarded as uncovered portions of a batholith, such as the hill between Thetford Mines and Black Lake, or between the west side of Black Lake and the Wolfestown road, the Belmina road, or the area about Little Lake St. Francis, serpentine occurs in the central part and is partially, or wholly, enclosed by pyroxenite, which in turn is generally bordered by a rim of diabase. The outer edge of the diabase usually contains fragments of the adjacent sediments and so passes into breccia. The accompanying cut (Fig. 3) shows the arrangement of the rocks as seen along a section from the Thetford river to Bisby creek. The section follows the power line of the St. Francis Hydraulic Company from the property of the Dominion Asbestos Company southward.

N.E.
THETFORD RIVER
Black Lake Station
Asbestos
Chromite
Carbon Lake
Chromite
Drift covered, probably sedimentary
Bisby Creek
Chromite
S.W.
Approx. Sea-level
Peridotite and Serpentine
Pyroxenite and Gabbro
Diabase
Brecciated zone
Sedimentary Rocks
DIAGRAMMATIC SECTION ALONG POWER LINE OF ST. FRANCIS HYDRAULIC CO, BETWEEN THETFORD RIVER AND BISBY CREEK
Horizontal scale 1 mile to 1/3 inch
Vertical scale 2640 feet to 1/3 inch

Fig. III.

A mile northwest of the northern end of this section the sediments dip towards the southeast at an angle of 70°, and within a few yards of the contact, four miles northwest of the section, the dip is 75° in the same direction.

The first igneous rock is usually diabase which in the outer portion sometimes contains fragments of sediment forming a breccia. Pyroxenite may be seen near the Roman Catholic church in Black Lake. The section is then drift covered until the serpentine is reached near the lake road. Following the line of section, the serpentine continues southward across the hill above the Standard and Dominion mines, though with a considerable amount of pyroxene in the higher and southern part of the hill, and passes beneath a heavy covering of drift. Near the Quebec Central railway, 560 yards north of Chrome siding, there is an exposure of pyroxenite at the south side of this serpentine area.

The drift covered area extends for two miles along the line of section until the second area of igneous rocks is met. This consists of breccia, diabase, pyroxenite, serpentine, pyroxenite, diabase and breccia in succession. The suceeding sediments stand vertically for half a mile south of the contact and at a distance of two miles dip towards the southeast at an angle of 75°.

It will be noted that Thetford river and Bisby creek occupy similar positions in erosion valleys, cut in the transition rock between the diabase and serpentine; that the general dip of the sediments on either side of the belt is southeasterly and that the dip, which is practically vertical near the contact on either side, is generally higher on the southeast than on the northwest.

No sediments have been found in the drift covered part of the section, but three miles west of the section, sedimentary slates strike towards this area nearly at right angles to the line of section. They dip away from each of the igneous ridges thus indicating a synclinal trough between them, which has been deeply filled with drift.

The structure of the serpentine belt as shown in this section, suggests a thick laccolith similar to that which contains the nickel deposits at Sudbury, but further investigation does not support the comparison very well. Parallel ridges such as occur there are not common, being found in only a few instances in the distance

of nearly 100 miles thus far examined. Such cases seem to represent the dying out of one intrusive ridge and the beginning of another near and parallel to it.

The dip of the sedimentary rocks is in the same direction on either side of the belt and at high angles. The arrangement of the rocks in the two ridges is the same, while if they were parts of a laccolithic sheet they should appear in reversed order on the two ridges. It, therefore, seems probable that the igneous ridges are formed along two lines, perhaps minor anticlines, which have afforded an easier ascent for the magma. They may be connected at no great depth beneath the sediments, yet they diverge sufficiently to permit of similar effects from differentiation taking place in each.

The arrangement of rocks by which the most basic rock is at the centre and the mass becomes more acid towards the outer edge is a common one in igneous intrusions of this class. It is theoretically accounted for by differentiation according to gravity taking place in a slowly rising magma thus bringing the more acid material, which formed the diabase and related rocks everywhere, in contact with the sediments. As the intrusion gradually rises, the acid margin is carried upward, forming an envelope over the advancing batholith. This is seen in this district in such hills as Broughton, Adstock and Big Ham mountains which rise in cone, or saddle shapes, and are encased in diabase in the upper portions. Near the bases of these hills the diabase passes into gabbro, and where erosion has been especially heavy, pyroxenite and in places serpentine are exposed at lower levels.

Location of Deposits—Thetford Phase.

Character of the Rock.—The asbestos deposits of the Thetford phase of rocks are found only in the purest serpentine. This in a general way is indicated by softness of the rock, but serpentine impure from the presence of soapstone is also soft, but is not as valuable for asbestos. Therefore soft serpentine is favourable for asbestos, only when there is no soapstone present.

As shown in the arrangement of the rocks above, the purest serpentine occurs in the lower part of sheets and in the central

portions of batholithic masses. As the trend of the serpentine belt is northeasterly, sheets in this district must dip either to the southeast or northwest. Where sheets dip to the southeast, as between Danville and Richmond, the best rock is found along the northwest side of the serpentine belt. In Garthby range II, where the dip is to the northwest, the best rock is near the southeast side of the intrusion.

In batholithic masses the purest serpentine, which would be found at the centre were the mass reduced to a horizontal plane surface, is best exposed around bases of the peridotite-serpentine hills, but especially near the north side. Thus the mines of Thetford are at the extreme northern edge of the serpentine hill which extends southwards to Caribou lake, and the mines of Black Lake are situated along the northwest side of the same hill. The King mine in Ireland is on the northern edge of the hill of serpentine and peridotite which extends southward to the Lambly mine in Coleraine, while the Belmina and Chrysotile mines are on the northern and southern borders respectively of the hill which separates them.

Effects of Erosion.—The better exposure of asbestos-bearing serpentine on the north side is due apparently to glaciation, the ice having eroded the hills on the north side, against which the glacier moved, more deeply than on the south, or lee side. While equally good serpentine may, and probably does, extend around and through these central hills it is generally covered by harder and less productive rock except where erosion has been especially heavy.

Asbestos has been found on the south side of two of the larger hills, at Chrysotile, and at the old Lambly mine near Coleraine, but the northern side has thus far proven more productive.

Serpentinization.—Besides the purity of the original peridotite, and its exposure by erosion, alteration to serpentine is a necessary condition for the formation of asbestos. The precise nature and cause of this change, from peridotite to serpentine and consequently the parts of the rock mass in which it is most likely to take place, are as yet imperfectly known.

Peridotite is a rock consisting principally of the mineral olivine, which is composed of silica, magnesia and iron. In the change to serpentine, water is taken in to the amount of about

12%, while iron and silica are probably in part removed. The serpentine thus produced is a softer rock than the original peridotite and shows few grains or crystal faces. Pure serpentine can thus be easily distinguished from fresh peridotite. But the greater part of the rock in the district is only partially altered to serpentine. Other conditions being equal, it appears to be more productive the farther the alteration has gone. Consequently the degree of alteration must be taken into account, and this is a somewhat difficult feature to determine. Hardness is in part a guide, but examination by means of the microscope is often necessary to certainly determine the degree of alteration of the rock.

An important part, at least, of the change from peridotite to serpentine is due to the action of water. Whether this is due to meteoric waters such as now circulate through the rocks, or to magmatic waters which came in with intrusions of igneous rocks is a question for further investigation, as it bears on the importance of the granites as an indication of asbestos. But in any case the water reached the rocks, which it has altered, by means of fissures and fractures which are, consequently, an important indication of the parts of the rock mass that are likely to be best serpentinized and to contain asbestos.

Fractures.—The parts of the rock mass which are altered to serpentine appear to depend in a considerable measure at least on the amount of fracturing of the rock, which is also a necessary condition for the forming of asbestos veins.

Where there has been much fracturing the rock is largely or wholly serpentine. Where other openings are not found the peridotite is commonly serpentinized along joint planes. In such cases veins of asbestos sometimes occur in a rock which, on the whole, is still a comparatively little altered peridotite. The hills on the south and west sides of Black Lake furnish a good example.

Serpentinization seems to proceed from any crevice into the wall rock on either side, and is generally followed by the formation of asbestos veins proportional in width to the band of serpentine. The asbestos veins in such cases are about one-third of the width of the serpentine band on either side of them.

The degree of serpentinization of the rock as a whole, and the amount of asbestos thus depends in a measure on the amount of fracturing. The fractures may be joints, or cleavage planes due

to regional foliations, or the casting off of concentric shells from rectangular joint blocks probably induced by increase of bulk due to hydration.

Fracturing is thus both a cause and an effect of serpentinization. But in either case it is an indication of well serpentinized rock, provided the peridotite were originally pure.

Where the rock is too greatly fractured the veins of asbestos become so short as to be of little or no value. Thus when serpentine is in contact with sediments it is usually finely shattered and the asbestos, if any, is too short to be useful and occurs as slip fibre. The shattering of serpentine near the contact also suggests a primary gneissic structure, but a determination of the full cause of it requires further study.

Influence of Granite.—As a result of experience the presence of granite in an area of serpentine is generally regarded as a favourable indication of the occurrence of asbestos but the causal connection, if any, is not easily apparent. Granite is often contemporaneous with the diabase and in some cases also with serpentine. In such cases the granite is in irregular masses, and it is difficult to see what connection they could have on the occurrence of asbestos beyond indicating a very complete differentiation of the rock.

In other cases the granite has been intruded a little later than the other rocks and forms dykes and sills. The fracturing which was accompanied by the injection of these dykes would favor the development of asbestos veins. Hence it is possible that they may be effects of the same cause, rather than that granite is any part of the cause of the occurrence as asbestos veins. It is possible and perhaps probable, as has been suggested by Dr. A. P. Low,* that the action of heated waters accompanying the injection of the granite dykes has aided in the serpentinization of the peridotite.

Broughton Phase.

The serpentine of the Broughton phase differs from that of the Thetford phase in being finely shattered and in containing asbestos principally in the form of "slip" or parallel fibre. It is also softer than the rock at Thetford and often has a talcose feel. Deposits of soapstone and sometimes of talc are found associated

*Report on the Chibougamau Mining Region, Geological Survey of Canada, 1906.

with it. It carries very little chromite even in disseminated grains and no deposits of important size. There is also no granite in the Broughton and related rocks, except in an isolated occurrence in the township of Tring, which probably belongs to this series.

The whole series occurs in intrusive sheets with the serpentine at the base, soapstone and greenstone schist, when present, in ascending order to the top of the sheet. In some cases, however, serpentine makes up the whole or greater part of the sheet and so extends to both walls.

In the serpentine there are blocks and masses of a harder rock which have not yet been examined microscopically and which contain no asbestos. These occur more plentiful towards the base of the serpentine and often make up the greater part of the rock near the lower edge of the sheet. Accordingly the pits are usually situated a little above the extreme base of a sheet.

SUMMARY.

The results of this investigation which seem to have a practical bearing on the location and estimation of asbestos, may be briefly summarized. Aside from the evidence of asbestos actually seen, the conditions which it is important to observe as far as known are:

1. Purity of the serpentine.
2. Fracturing.
3. Presence of granite.

1. The purity of the serpentine is the most important feature. It depends on (a) the purity of the peridotite, or original rock. (b) Its degree of serpentinization.

(a) The purity of the original rock depends on the composition of the magma and its differentiation in cooling, the latter factor being largely influenced by gravity. The purest serpentine is accordingly found at the base of sills, or intrusive sheets, and in the central portions of batholithic masses.

The exposure of the central parts of batholithic masses depends in a large measure on glacial erosion, which, in this district, has uncovered the most productive rock on the north side of the larger hills.

(b) The fractures are due to jointing, and regional compression; also probably to the increase of volume accompanying ser-

pentinization and possibly to original flow structure around the margin of batholithic intrusions. Hence they are likely to be more abundant around the edges of serpentine and in zones of special regional foliation.

3. The granite, where intrusive, has accompanied a fracturing of the peridotite, a condition which is favourable to the formation of serpentine and asbestos. Magmatic waters accompanying the intrusions may also have aided in serpentinization. Granite dykes are therefore thought to be a favourable indication of the presence of asbestos veins.

Discussion.

The President.—I would like to ask Dr. Coleman if these rocks have any similarity to the rocks at Sudbury.

Dr. Coleman.—I have been extremely interested in this paper; but perhaps, principally from the point of view of a side issue, namely, in regard to the sheet which, I understand, was apparently diabase in the upper part, and serpentine at the bottom, and the fact that Prof. Dresser looks upon this as having been due to gravity. That is the view I have held for a long time regarding the Sudbury ores, and it is very interesting to have a corroboration of this kind from Prof. Dresser. I should also like to draw attention to another parallel instance recently noted. I refer to that at the Alexo mine, in Northern Ontario. I had the good fortune to visit that mine last summer, and there found something very like the Sudbury sheet; that is to say, we have a sheet of what was olivine at one time, but which is now transformed into serpentine, tilted very much in the way Prof. Dresser described, with pyrrhotite and other sulphides collected at the bottom. Evidently gravitation was a very important factor there, so that the Sudbury region and the Alexo deposit support the relationship as instanced by Prof. Dresser. It is, perhaps, worth mentioning also that asbestos of excellent quality occurs at the Alexo mine, though the fibre is, at greatest, only about a quarter of an inch in length.

MR. OBALSKI.—I may say that last summer I saw some very fine specimens of asbestos showing half-inch and even one-inch fibre, that came from northern Ontario. I understood it was from the Maple Mountain district (near Montreal river). I would meanwhile like to ask Prof. Dresser what he means by serpentinization, and if he considers serpentinization to be more prevalent at the surface or at depth.

DR. BARLOW.—There are one or two ideas expressed in Prof. Dresser's paper that I should like to emphasize, more especially in connection with other intrusive bodies of rock. Mr. Dresser regards the foliation noticed in some of these rocks as an original structure, and in so doing reaches conclusions which were strongly insisted upon by me some years ago in the summary of a paper* which Dr. Adams and I intended to present to the Geological Society of America, explaining and illustrating this foliation. Anyone who works in Archæan rocks is impressed with the fact that the greater part of the foliation of the genisses is an original structure; that is to say, it has been induced in the rock mass before its final and complete consolidation. In connection with this paper it was intended to bring forward certain well-defined and typical examples, the results of personal experience, illustrative of the fact that original foliation is the normal or prevailing structure which persists over great areas of these Archæan gneisses. This frequent and widespread parallel structure is explained in general by assuming that these immense batholiths, during their period of intrusion, are subjected to prolonged and often intense differential movements and pressures, which, before the complete crystallization of the magma, results in the parallel disposition, not only of the component minerals, but also of certain bands of varying basicity.

With regard to the occurrence of asbestos, the two important questions remaining to be settled are in regard to the depth of asbestos, and whether asbestos becomes better or worse in depth.

It seems reasonable to suppose that the dykes of granite cutting the serpentine, are the upward expression of a buried mass of ganite which deep mining will eventually reach. It also seems reasonable to predict that asbestos in the vicinity of this granite

*Annual Report Geological Survey of Canada, Vol. x, 1897, Part I, page 60 et seq.

will be very similar to that found in the vicinity of East Broughton. Prof. Dresser in his paper touches upon the question of the relative ages of the East Broughton and Thetford asbestos, suggesting in a tentative sort of way that the East Broughton serpentine is an older formation. I would like to ask him what evidence he has on this point. I think it would be well, moreover, that such evidence should be reasonably strong, because in most areas where these rocks have been studied in different parts of the world they have in the several instances been regarded as each forming a single geological unit. Similar rocks from New Zealand have been subjected to a very critical study, and the results published in a recent number of the Journal of the Geological Society of London. It is the writer's idea, here expressed, that the New Zealand peridotites belong to one geological age. This is the consensus of opinion of most geologists in regard to similar occurrences of these rocks in North America, which outcrop at intervals all the way from Alabama to Newfoundland. As serpentinization properly so-called is not necessarily connected with any process of weathering and is, in my opinion, a deep seated action, it seems reasonable to suppose that asbestos being present would, within certain limits, improve in depth. Deeper still and in the vicinity of the granite "massif" or batholith it would be over developed, resulting in the destruction of the cross fibres and the development of an undue proportion of slip fibre. Future investigations should, in my opinion, be directed to the determining as far as possible not only what is the direct cause of the development of asbestos, but also the depth to which it may be expected to continue.

PROF. BAKER.—Mr. President, while working in the Abitibi district of Ontario two years ago, I came across rocks that I took to be simply basic dykes. These I might say were Keewatin but on examining them with a microscope, I found afterwards that they were filled with original olivine crystals. They were largely meshed with serpentine, and of course proved that those rocks were originally peridotites, and for that reason I have devoted some attention to the study of these rocks.* Many of

*A detailed description of this occurrence is contained in a paper contributed by H. T. White on "The Chrome Bearing Peridotites of Lake Abitibi," and published in Vol. XII, Trans. C.M.I., p. 592.

the points raised in this discussion have been interesting, particularly so Dr. Barlow's question whether we should consider serpentine from olivine as a secondary product in the sense that it immediately followed the production of the olivine itself, or secondary in the sense that it is the result of weathering; that is, make a distinction between weathering and deep seated alterations.

In my opinion the serpentine that we now find is not the result of weathering. I believe it to be a secondary alteration more or less connected with the end phases of the intrusive mass itself. As evidence of that I would point out that we find other olivine rocks, such as our olivine diabases and olivine gabros, in which olivine is still fresh. Now, if it is the nature of olivine to change to serpentine through the ordinary process of weathering, why is not this change general? If it be not solutions of a similar kind, which are characteristic of the intrusive mass itself, it seems to me all olivine should undergo much the same changes.

Another point that I would suggest as explanatory of the sharp contact between the serpentine and the adjoining rock, has been indicated very clearly by Mr. Dresser; I refer to the character of contact existing between the vein and its wall rocks, or between cores of the original olivine and the serpentine along the cracks in the olivine. It appears to me that, since the composition of the serpentine and the original olivine is practically similar, the sharp contact is due to a structural re-arrangement of the material, rather than a vital chemical change in the material.

Regarding the depth to which these materials should attain, if there be accompanying actions of the original intrusion, then they should certainly continue as deep as the original intrusion itself. I can conceive of no reasonable cause why values should either improve or diminish. I cannot see that what we look upon as weathering conditions have very much to do with the case.

DR. IRVING.—Dr. Barlow's paper and likewise that presented by Mr. Dresser, contain a number of rather important inferences concerning the origin and character of serpentinization. If I correctly understand Dr. Barlow, he assumes that the formation of the serpentine in the occurrences which he has described is the result of magmatic waters that have operated at a very con-

siderable depth below the surface, and that the alteration of olivine into serpentine, as well as the formation of the asbestos veins, is not the result of weathering. Although I speak on this point without having gone very carefully into the question of serpentinization in general, it seems to me that there are some things which it will be necessary to explain if this view is a correct interpretation of the facts. The members of the Institute will probably recall that in his paper on metasomatic processes in fissure veins, Mr. Lindgren has briefly discussed the chemical reactions which may be assumed to have taken place in the origin of serpentine.* These equations do not, it is true, represent the actual conditions occurring in serpentinization, as we cannot be certain of the correct formula; they, however, serve to show that in processes of serpentinization, when water is added to the elements present in the rock an increase of volume takes place of from 20 to 50 per cent. It is difficult to conceive of an equation which will explain this process that does not involve a very large increase in volume. If we conceive serpentinization to be a process which is essentially superficial and the result of deep-seated weathering, it is easier to account for an increase in volume of this kind, because the expansion of the rock masses as a whole during the transformation into serpentine may find relief upwards, and will not involve the intense compressive stress necessary in the case of a completely confined mass. The deep-seated serpentinization of a mass of olivine rock, on the other hand, involving as it does, the production of an enormous amount of additional space, is something which cannot be readily explained. I hesitate, of course, to base too much upon this one phase of the question, especially as I have not studied the occurrences which Dr. Barlow has described; but it seems to me that if the formation of serpentine is to be regarded as the result of magmatic solutions, and not as a surperficial process, this question of volume is one which the advocates of the magmatic view will be obliged to explain. From my observations in such areas as I have been able to study where serpentinization has occurred on any considerable scale, I should look upon it rather as a superficial process, more probably due to the conditions of weathering than to any other cause.

*Trans. A.I.M.E. Vol. xxx., pp. 591-592

DR. BARLOW.—I am sorry to have to take issue with Dr. Irving's remarks in this connection, but my opinions have been formed after studying these rocks both in the Province of Quebec and further to the south in North Carolina. In my opinion the processes of weathering and serpentinization are quite distinct and separate. There can be no reasonable doubt, however, that some serpentinization and certain serpentines are the direct result of the action of meteoric or surface waters. Still, serpentinization with economically valuable asbestos can only be attributed to deep-seated action, the direct result of magmatic waters. Much of the recent literature on the subject admits this statement, and many writers place strong emphasis on magmatic waters as the sole cause of serpentinization. It is true, as Dr. Irving has pointed out, that the development of serpentine from dunite or peridotite involves an increase in volume of from 20 to 40 per cent. The question as to how such a change in the volume of a deep-seated mass could find relief cannot at present be explained; but in Quebec the inclusive rocks of the serpentine show abundant evidence in very pronounced fracturing and brecciation the immense strains to which they have been subjected, probably due to this enormous increase in volume of the secondary serpentine. It is, moreover, significant that in the Province of Quebec, where weathering processes have been least active, serpentinization has been most pronounced, while in the southern Atlantic States where these conditions are reversed furnish most abundant and extended outcrops of practically unaltered dunite and peridotite.

MR. D. H. BROWNE.—I really think Dr. Barlow is taking an unfair advantage in bringing up this discussion in Mr. Hixon's absence. I think the question of magmatic waters should be kept in the dark until Mr. Hixon's return. (Laughter.)

THE PRESIDENT.—Unfortunately Mr. Hixon has deserted us and turned his attention to the Institution of Mining and Metallurgy.

PROF. WALKER.—Referring to the process of serpentinization, there is another feature not referred to here and that is that Holland in his studies of the olivine rocks in India has found a remarkable state of affairs. He has found for example that if these olivine rocks—which from their age have apparently been intruded since the Peninsula has been above high water—that

in some of these there is a remarkable freshness, while in the case of the olivine rocks that are older than the last dip of the peninsula of India, he found serpentinization extremely prominent. One might think that that is just a difference of age—that the younger ones are fresh and the older ones serpentinized; but he seems to think there is something more than that.

Dr. Adams.—I wish to express my appreciation of Prof. Dresser's and Dr. Barlow's papers, and in so doing I am sure I express the appreciation of all who are acquainted with the Eastern Townships, for this district has always presented peculiar difficulties in the interpretation of its structure. One geologist after another has gone there, done a certain amount of work, written a paper or two, and has then abandoned it for some other field to which he felt his efforts could be more profitably directed.

I remember that after Sir William Logan had been working in that district for many years, he sent one of the younger members of his staff to make a section from one point to another across the range, which section very carefully measured he thought would definitely settle certain problems. There were three distinct but naturally contradictory interpretations of the structure of the country which might be adduced, and when this young man came back he said he thought the section had conclusively proved all three hypotheses. (Laughter.)

It is a great pleasure to find that we now have two gentlemen working in the Eastern Townships who are thoroughly conversant with modern methods and abreast of modern knowledge and who are evidently ascertaining that the various problems, which present themselves in the Eastern Townships are capable of solution along the lines which have been found to hold true in other districts whose structure is fully understood.

When we hear of granitic juice and batholitic intrusions, we feel ourselves in well known fields, and I am sure, as this investigation goes forward, that we shall obtain a great deal of light on the structure of this very complicated region which will be of value in the development of its mineral resources. (Applause).

Mr. Dresser.—I am glad of the corroboration of the effect of gravitative adjustment in the differentiation of end rocks that is furnished by Dr. Coleman from two localities in the north of

Ontario, and to find that we have these evidences to strengthen our supposition as to how these bodies are formed.

The question raised by Mr. Obalski is an exceedingly important one, that is concerning the depth of asbestos deposits. I omitted to say when speaking before, that our chief interest in finding out whether we had laccoliths or batholiths, is that, in the case of laccoliths there would be a limit of depth which we sometimes reach, while in the case of batholiths asbestos may be expected to extend to any depth at which it could be mined.

Dr. Barlow has also given a corroboration of the idea of original foliation around the edges of an intrusion, which of course is only tentatively held by us at present. It is a somewhat important factor since at the edges of these intrusive masses we sometimes get very rich rock—not large veins, but a large number of small veins making a high percentage of asbestos in the rock.

Dr. Barlow also questions the relative ages of the serpentine of East Broughton and the serpentine of the Thetford mines. The reason for thinking these of two different ages, is not found so much in the serpentines, although they are quite different in their state of preservation, but in the other igneous rocks associated with them. The serpentine of Thetford occurs with diabase and pyroxenite which preserve their original structure, and are not greatly foliated, while with the serpentine at East Broughton instead of pyroxenite and diabase there occur soap-stone and a sheared greenstone whose original character has not yet been determined satisfactorily. It probably was originally also diabase or some related rock. The evidence is chiefly found therefore in the greater metamorphism in the case of the rocks at East Broughton than in those at Thetford.

The question raised by Professor Baker as to the cause of serpentinization is one that awaits further investigation. Serpentinization of the peridotite in this district appears to proceed from joint planes and other fractures rather than from the present surface of the rocks. In the walls of pits joint blocks may be seen which have a core of peridotite enclosed in serpentine. Where a considerable part of the rock has been serpentinized it becomes shattered into small pieces which generally have slickensided surfaces. This was thought by Logan and Hunt to be caused

by the increase in volume of the rock due to hydration, one of the principal changes that takes place when olivine passes into serpentine being the addition of 12% to 15% of water which gives a still greater increase in volume.

The serpentinization seems to be as far advanced at the bottom of the deepest pits—about 200 feet—as at the surface. All that can be said at present, is that serpentinization requires the presence of water; that in this district large areas of highly basic rocks have been serpentinized, some of which are remote from any known intrusion of granite or other acid rocks; that serpentinization has begun and proceeded from the joints and other natural courses for circulating waters; and therefore it seems probable that serpentinization is due not to direct atmospherical action but to ground waters which were probably of meteoric, rather than of magmatic origin.

The analagous cases pointed by Dr. Irving and Dr. Walker seem to corroborate these conclusions.

Regarding Dr. Adams' remark that the history of geological investigation in the Eastern Townships is a badly tangled one I am sure that all who have to do with the region will thoroughly agree with that sentiment. But it is our duty to continue the investigation and our aim to make it as thorough as possible.

"SOME NOTES ON THE ORIGIN OF ASBESTOS."*

By A. E. BARLOW, Montreal, Que.

(Annual Meeting, Toronto, 1910.)

These few observations regarding the origin of asbestos are made at the present time in order to correct in a measure certain misconceptions which may have arisen in the minds of many, as the result of previous descriptions of the origin of this mineral. The remarks are believed to be especially appropriate at this time, because of the recent merger of many of the principal mines and properties, although the somewhat tardy recognition of the mineral's many valuable properties and consequent wide usefulness have, no doubt, contributed to this greatly increased attention. These factors are, however, being taken advantage of to bolster up the usual promotion schemes, some of which may be legitimate, but more are doomed to failure, on account of the scarcity or unsuitability of the material sought to be exploited.

Without a shade of doubt the Province of Quebec has the greatest deposits of the highest grade of asbestos in the world. Unfortunately, however, the subject of asbestos, from a mining geological standpoint, has received very scant attention at the hands not only of scientific men, but even from the Government geologists in the way of exact investigation. Personally, until the past summer, I had no opportunity of examining any of these deposits in detail; and the present observations are based on examinations of individual properties with a view to determining their commercial value, and are not conclusions arrived at as a result of very extended research respecting the origin of the mineral.

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* In presenting this paper at the Annual Meeting at Toronto, the author remarked: "I have to apologize to the Meeting as I have no set paper, and the title, 'Some Notes on the Origin of Asbestos' was communicated to the Secretary that I might have the opportunity of making a few remarks regarding the genesis and geological association of a mineral which has contributed so much in value to the mineral production of the Province of Quebec."

In the first place the asbestos of commerce includes several distinct mineral species, chiefly hornblende and serpentine, although some of the fibrous varieties of pyroxene are also included. These fibrous varieties of serpentine and hornblende are what are usually described as secondary products. There appears to me to be a wrong conception as regards the precise meaning of the word "secondary," used in this connection. I am a follower of Vogt in his conception that "secondary" in the case of these minerals is descriptive of the effect produced by certain eruptive after-actions. There is no extensive intrusive process in nature which is the direct result of dry fusion, and all eruptive action is accompanied by a varying but usually large amount of water, especially towards the end of the process, and immediately preceding the complete consolidation of the resulting rock mass. The action of these magmatic waters and vapours produces certain alterations in the mass and its component minerals, which are usually classified under the name of "secondary"; while the resulting products are also included under the same name.

Various explanations and theories have been advanced by different writers to account for the presence of asbestos; but most of these have failed to take into proper consideration, or give proper value to, the evidence furnished by the microscopic examination of the thin sections of the rocks containing this mineral. Asbestos or chrysotile is really a fibrous serpentine, a rock which in its purest form results from the alteration of olivine. The fresh rock is called dunite and much of it is made up almost wholly of the mineral olivine, with sometimes a little chromic iron ore and pyroxene as accessory or accidental constituents. Olivine is very alterable in the presence of water, especially heated water, so that it is seldom that a perfectly fresh dunite is found. Thin sections under the microscope show all stages of this alteration as a result of the secondary action already described. The grains of olivine are converted into fibrous serpentine or chrysotile just around the edges and then along certain lines of fracture, which traverse the various individuals in different directions. This alteration proceeds until the whole individual is replaced by the secondary serpentine. Some of these small fractures filled with fibrous serpentine (veinlets) are very irregular in their development; while others follow certain well defined and more or less

regular structural planes of the mineral. Now, if one of these microscopic thin sections is taken and studied, we have on a minute or microscopic scale what actually takes place on a larger scale in the working face of a quarry. We find, moreover, as Mr. Woolsey has so well pointed out in his paper, and as Mr. Dresser has emphasized, that the formation of asbestos really commences along a line, and extends outwards from this as a centre. Again most of the previous descriptions of this mineral, it is observed, give expression to the idea that the asbestos-bearing serpentine has undergone contraction, whereas the very reverse has been the case, and the secondary serpentine is really from 20 to 35 per cent. greater in volume than the original or fresh dunite from which it has been derived. The so-called veins are really cracks formed almost if not quite *in situ*, and growing in direct proportion to the amount of magmatic water or *granitic juice* supplied in the later stages of its formation. The asbestos or chrysotile has not been transported from a distance, and has, therefore in this respect no relationship with ordinary veins. They owe their presence in such purity and abundance in the first place because of the great purity of the original rock and the presence of an ample supply of magmatic waters, due to the pronounced differentiation of the whole rock mass, especially towards the acid or granitic types which is a marked and almost unique feature of the Thetford and Black Lake fields.

The origin and formation of asbestos must not only be ascertained by extended examination of the field occurrences of the mineral, but also by very critical and detailed study of the thin sections under the microscope.

The commercial asbestos of Quebec, or chrysotile, as it is known to the mineralogist, is in reality the crystalline form of serpentine. It is the best attempt that serpentine can make in the way of crystallization, the various fibres being, perhaps, a greatly exaggerated form of the prismatic crystals. The large "veins" so-called are but the giant form or expression of the minute fibrous serpentine, with which all petrolographers are familiar in studying thin section of altered olivine or dunite under the microscope. Their shape, mode of occurrence, and genesis are identical.

We do not yet fully understand all the types of rocks which may be represented in this complex; but this information can be obtained from Mr. Dresser, who is conducting a very detailed examination of these deposits for the Geological Survey Branch of the Mines Department at Ottawa.

This dunite or serpentine and associated rocks form a belt which with certain breaks or interruptions extends from Alabama to Newfoundland, a distance of over two thousand miles. They form large lenticular masses associated at intervals with certain crystalline schists and gneisses; but it is only under the favourable geological conditions which have been described, and which are so eminently present in the Province of Quebec, that the asbestos of commerce is developed. If the asbestos is formed quietly, and with a minimum of motion, the longest, silky, uninterrupted "cross" fibre is produced; whereas if the rock is subjected to violent and prolonged stretching or dislocation, abundant picrolite (the hornblende of the miners) or "slip" fibre is produced. My first studies of picrolite of serpentine inclined me to the belief that this variety was really under-developed asbestos. As a matter of fact it really represents both the under-developed and over-developed asbestos.

The question of the origin of this as well as other minerals has a very important bearing on the question of the economic importance of these deposits, and I have brought the subject forward to show that although the Mines Branch of the Department of Mines at Ottawa, has issued a monograph on Asbestos, they have entirely failed to give a satisfactory answer to what are really the fundamental questions, viz., (1) What is the origin of Asbestos?; and (2) What is the depth to which these deposits may be expected to extend? The question of the depth depends directly on the origin.

These are the great and fundamental questions, not only in regard to asbestos, but also in respect of any mineral deposit. When we find a mineral and can study satisfactorily its origin and natural history, we have removed many of the doubts which previously existed as to its true economic importance. All other questions are and must be subsidiary, and I think that the origin of our mineral deposits should be one of the main if not the principal question to which the Government geologists' attention

should be directed. It is not so necessary to know the most successful processes by which we may hope to win the minerals from their ores, but first of all in this vast and for the most part unprospected country, to determine the location and size of our minerals deposits as well as their geological environment. The discovery and delimination of economically valuable rock formation is one of the primary and most useful functions of a government department of mines. If our efforts are more concentrated on the economic geology of our hinterland we will make much more rapid progress, than by spending the larger proportion of our time and money in conducting investigations looking to the winning of the various metals from their ores.

DISCUSSION.

MR. MURRAY:—If I have been credibly informed, I understand that Dr. Barlow has in connection with his researches in this district, coined a new phrase—the phrase of "granitic juice."

DR. BARLOW:—I may say that I have not coined this phrase, granitic juice. It has, I think, been repeatedly used by certain geologists. It is certainly an expressive though perhaps not strictly scientific phrase, as it gives at once a very correct and descriptive impression of what has taken place. If you get granitic juice or magmatic water traversing strata, you know that there is, to use a common present day colloquialism, "something doing."

MR. MCEVOY:—I would like to ask Dr. Barlow this question: Assuming the so-called veins of asbestos originated in the manner he described, how does he explain the sharp lateral limitation of that deposit so that it so closely resembles the edge of a true fissure vein?

DR. BARLOW:—I would answer Mr. McEvoy's question in this way: These magmatic waters were most active towards the end of the old intrusive process immediated prior to the complete solidification of the rock. These solutions were very active in traversing certains cracks which have a definite relationship or are coincident with the structural planes of the rock. The magmatic waters seem to have acted very uniformly on either side of

the various cracks or fissures, but the lines are by no means as sharp or regular as one would suppose after an inspection of these deposits. Some of the large veins may have been formed by the coalescence of one or more parallel cracks. If the rock is very uniform, as it is in most cases in the Eastern Townships, the magmatic waters will act with equal facility on either side of the crack, and to a certain distance; but if you look under the microscope, you will find that there are certain places at least in the smaller veins where the solutions have formed angles or bays in the otherwise rather uniform wall, but in most cases the action has been singularly uniform and regular, extending outward from a centre or medial crack. The "veins" are, therefore, not made up of transported material. They are really formed *in situ*.

MR. DENIS:—In a case of two very small veins in certain cases, do you not find serpentine between these two veins?

DR. BARLOW:—Yes, sometimes we do. The subject is a very difficult and intricate one, and not very easy of explanation in all its different phases, and the matter was only brought forward at this Meeting in order to correct certain very grave misconceptions which have appeared in the government and certain other publications which should be authoritative.

ON METHODS OF MAKING LARGE SCALE CONTOUR SURFACE PLANS OF CLAIMS OR MINING PROPERTIES.

By W. H. BOYD, Ottawa.

(Annual Meeting, Toronto, 1910.)

The attention of the writer has frequently been called to cases where large scale contour plans of mining claims were being made for companies or individuals by methods that were cumbersome and entailed considerable expenditure of both time and money. It is the purpose of this paper to suggest some methods that can be employed at a comparatively small cost, with results that would be sufficiently accurate for most purposes for which surface plans are needed. The instruments to be used are those found in every mining engineer's or surveyor's office, namely:— a good transit, steel tape and levelling rods. By the method to be described a company might obtain a contoured surface plan of its property or properties, at practically no cost, provided the resident engineer were to devote spare time to the undertaking.

The use of the transit and stadia, with perhaps a triangulation control if the area to be covered is extensive, will comprise the method.

Two years ago the writer read a paper* before the Institute on "Topographical Methods used for the Special Map of Rossland, B.C." Therein the transit and stadia method was described. The present paper is therefore in the nature of a further adaptation of these methods to smaller areas on larger scales.

The advantages and accuracy obtained with the stadia are important. The advantages lie in the fact that in one sighting

* Jour. Can. Min. Inst., Vol. XI (1908) p. 373 et seq.

of the instrument, the distance, direction and difference of elevation of the point sighted to are quickly determined; and from one set up of the instrument, this information may be obtained concerning several points, the inequalities of the ground forming no obstacle whatever in their location; this is a great factor in regard to the speed with which the work can be done. The error of the stadia is usually given as about 1 in 600 horizontal measure; but many instances can be cited where it has averaged as low as 1:1800, or less. Distances to within the foot can be easily read as far as 800 feet, providing the light is good, the telescope has a fair magnifying power and the atmosphere is steady. So it will be seen that by limiting the sights to less than 600 feet, distances can be readily determined to within half a foot, and this it would seem is quite accurate enough for most purposes for which a surface plan is used. Differences of elevation are found with a corresponding degree of accuracy.

In carrying on the work with transit and stadia for a large scale map, the following precautions must be observed in order to ensure good results:—

1. The interval between the stadia wires, which is generally given in the ratio of 1 in 100+ the instrument constant, should be carefully checked. This is best done by testing the readings of the rod over different known lengths. If found to be in error, the correct wire interval should be determined and this used throughout the work.

2. A rod level should always be used to ensure that the rod is held in a vertical position: it will be readily seen that an inclination of the rod will give a wrong distance reading.

3. The inclination of sights should not be greater than about 20 degrees, and when reading steep sights the centre wire of the telescope should be at about the same height on the rod as the telescope is above the ground; or, in other words, the centre wire should always be reading near the mark corresponding to the height of instrument.

4. The length of sights should be such that the rod can be read distinctly.

5. The instrument should be carefully centred over the station mark; the distance and vertical angle of both back and fore-sights between stations should always be read.

6. The edge of the rod, held exactly over the station mark, should be used in sighting to a station for direction. By observing these precautions the best results will be obtained. It is assumed that the transit used is one in good adjustment, and is provided with a telescope having good illumination, flat field, and of a moderately high power.

The methods of keeping the notes and of reducing them in the office has already been described by the writer.*

The quickest way of handling the instrument when using the stadia is found to be as follows:—First sight to the rod for direction; if the sight is taken to a station, the direction should be read immediately after sighting to the edge of the rod and the rod then turned face toward the instrument for the reading; while, on side shots, the direction may be more conveniently read after the rod reading has been determined, since the face of the rod is sufficiently accurate for sighting to for direction; then place the centre wire of the telescope near the mark corresponding to H.I. (Height of Instrument); with the slow motion of the vertical circle, move the telescope till the lower wire bisects the nearest even foot mark; read the intercepted distance between the stadia wires. The setting of the lower wire at an even foot mark is merely for convenience in making a quick subtraction between the numbers, in order to determine the rod reading. After determining the rod reading, move the telescope, again by the slow motion of the vertical circle, till the centre wire bisects the number corresponding to the H.I., then read the vertical angle.

The application of the stadia method will differ somewhat with the nature and extent of the ground to be covered, the contour interval and the scale. In the following pages some suggestions will be given for applying the stadia method to certain cases where the conditions differ both as regards scale, contour interval, nature and extent of ground, the results being quickly obtained and accurate enough for the scale and contour interval selected. All the claims are considered as being 1,500 feet square.

Case 1.—Single claim, open country, differences of elevation rather great, scale 40 feet to 1 inch, contour interval 20 feet.

Case 2.—Single claim, open country, differences of elevation small, scale 40 feet to 1 inch, contour interval 5 feet.

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* Jour. Can. Min. Inst., Vol. XI (1908), p. 380.

Case 3.—Same as Case 1, but over timbered ground.

Case 4.—Same as Case 2, but over timbered ground.

Case 5.—Group of claims, open country, scale 100 feet to 1 inch, contour interval 20 feet.

Case 6.—Same as Case 5, but over timbered country.

Case 7.—Same as Case 5, but with 5 foot contour interval.

Case 8.—Same as Case 6, but with 5 foot contour interval.

Case 1.—It might be well to keep the length of all side sights at or about 400 feet. A very good rod reading is thus ensured, and in plotting the work no line exceeding 10 inches in length (400 feet) would require to be plotted. This length of line can be readily plotted with minute reading protractor of about 10 inch diameter. The length of side sights would be governed to a great extent by the facilities the engineer has in the office for accurately plotting the directions of long sights. By limiting then the length of side sights to about 400 feet, it will be seen from Diagram 1, that five stations (the distances between them being 600 feet) would be the least number that could be used in order to obtain all the information over the whole claim. In a few cases the length of side sights would be over 400 feet, but not greater than 500 feet. The diagram shows an ideal case, as more stations would probably be necessary owing to some of the sights being obstructed by buildings, dumps, etc., or by the inequalities of the ground limiting their lengths. The main stations should be kept, however, in some such relation as shown in the diagram and side stations set from these to get the necessary information not obtainable from the main ones. All stations should be carefully selected so that the fewest number possible would be used.

The central station should be located as near the centre of the claim as possible. The transit is set up over this station and oriented in any position, the other four main stations should then be carefully set; the side sights are then taken around in a complete circle to all points for the detail, such as to corners of buildings (two corners being necessary to get a proper orientation of the building), to shafts, tunnels, prospects, open cuts, bore holes, tramways, ore bins, on roads and trails, to points on all streams, drainage lines, flumes, etc., and also to points that will give the best information for the contouring of the plan. These last mentioned points, called contour points, should be taken at all

changes of slope, along tops of ridges, bottoms of ravines or depressions, tops and bottoms of knolls, etc., or, in other words, to all points that give the most information concerning the surface of the ground. By a proper selection of these points and with their elevation and those obtained for all the other detail, sufficient elevations can be had for the proper sketching in of the 20 foot contours.

When occupying any of the other four main stations the instrument should be oriented by setting on the back sight to the central station, and the distance and vertical angle again read. By reading on to the other two adjacent stations a check may be had on their setting from the central station. Sights to the corner posts of the claim and to points on the side lines should be taken from these stations, in order that they may be drawn on the plan, and thus locate the positions of all the stations with reference to the claim lines and posts.

All the elevations of the map are referred to the datum used by the mine, or to any other chosen by the surveyor as being the most suitable. The datum should be stated on the map and marked in the ground in such a manner as to be easily recovered.

The direction of the claim lines when drawn will give the position of the north and south line on the plan if required.

By setting a station on an elevated tramway or on a shed, a more complete view may be obtained of the area to be taken from that station.

It will be seen that in a very short time, by the stadia method, all the necessary data can be obtained in the field for making a plan of one claim under the conditions mentioned above. The plotting can be done at leisure, and when all the points are plotted, the buildings, roads, etc., all laid down and the drainage sketched, the contours can be interpolated between the known elevations and drawn on, provided the contour points have been well selected; or else a tracing of portions of the plan can be taken out in the field, and the contours drawn on more accurately.

If the claim were situated on a steep open mountain side, the method of selecting the stations would be somewhat different, as a sight straight up or down hill might perhaps give a vertical angle that would be too large to give a good horizontal distance. The direction of the sights would be limited by the amount of the

vertical angle. The stations, therefore, would have to be selected in such a manner that all vertical angles would be under the 20 degrees. Diagram 2 gives a suggestion of a method in which the stations might be selected so that the whole claim would be covered, using side sights limited to about 400 feet, the vertical angles of which are under 20 degrees. If the first station were set at *A*, about midway on the lower side of the claim, then let *A* to *B* and *A* to *C* represent the direction of the sights to the stations *B* and *C*, the vertical angles to which are about 20 degrees; it will be seen then that the stations set from *B* and *C* would be *D*, *E* and *F*, assuming that the slope is a uniform steep one over the whole claim; and so on to *C* and *H*, etc. From each of these stations the areas are covered by side sights, 400 feet in length, are shewn by the arcs drawn from each one of these stations as centres. The selection and number of the stations will of course vary with the nature of the ground and its slope, but the best results would be obtained by selecting them in some such manner as shewn in the diagram. If the slope were timbered the method of selecting the stations would be the same; but the number would be increased owing to the limited area visible from each one.

Case 2.—The selection of the stations would be the same as in *Case* 1; but the method of taking contour points might differ, because it might be easier and quicker to practically trace out each contour. This becomes a simple matter with the stadia. The elevations of the stations, however, must be determined in the field as soon as they are established. The contours can then be traced out at the same time as the detail is taken, or, if more convenient, can be traced out afterwards. The method of tracing the contours with the stadia is as follows:—Suppose the elevation of any station was such that it came 3 feet above and 2 feet below adjacent 5 foot contours. Let the *H.I.* be 4.5 feet; it will be seen by the illustration that when the telescope is level, if the rod were held at any point so that the 2.5 foot mark on the rod is cut by the centre wire, that point is on the next contour above the station; and again, if the rod were held on any point so that the centre wire cut the 7.5 and 12.5 foot marks, those points would be on the next two contours below the station. A rod reading for distance locates the point at which the rod was held. The contours are traced out in this manner three at a time. The rodman after

DIAGRAM 1

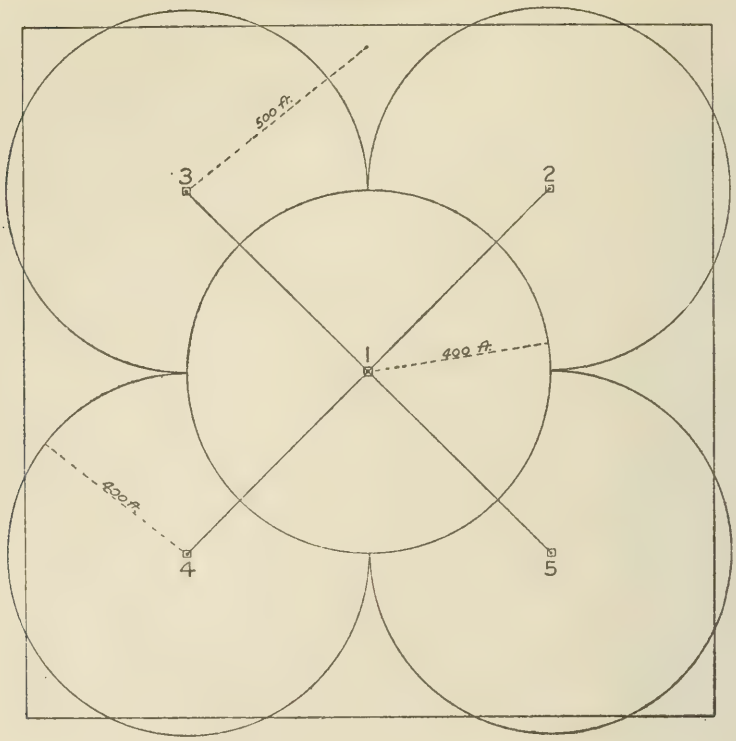
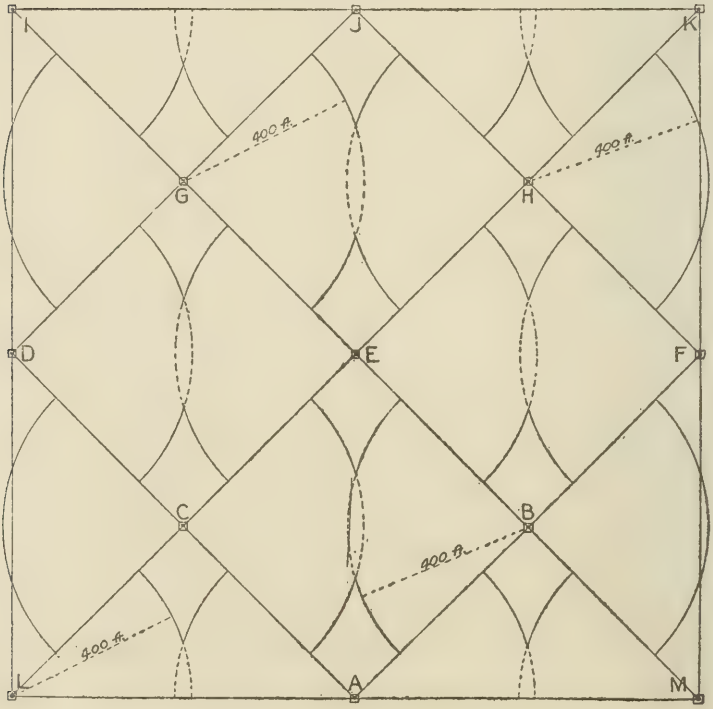


DIAGRAM 2



being put on a contour by the instrument man in the manner described, follows it along giving points at all changes in the direction of the contour as far on each side of the station as is possible consistent with a good rod reading, and so on with each contour. It will be seen that with a 14 foot rod, three contours are the greatest number that can be traced from any one station; other stations are located in order to continue the tracing of these contours, and all others on the claim. If the station is on a contour, that contour is traced by sighting to the *H.I.* on the rod when the telescope is level.

Case 3.—Establish stations on the claim lines by running a closed traverse around these lines, tying on to the corner posts, side sights being taken wherever possible. Having then the positions and elevations of these stations, run traverses across to the opposite side of the claim between the fixed stations on the lines, taking side sights wherever possible and making use of every open space in the timber in order to get the greatest number of sights from any one station. Run enough of these cross traverses to obtain sufficient information over the whole claim to put in all the detail and 20 foot contours. The surveyor will naturally select the best routes for these cross traverses in order that very little cutting of timber will be necessary and consequently time saved. Diagram 3 illustrates the method suggested.

Case 4.—A combination of the methods suggested for Cases 2 and 3 with any variation suitable to conditions.

Case 5.—If the claims have all been properly surveyed and connected, the quickest way of making a contoured map of the area would be to take the topography of each claim separately in the manner described for Case 1. The number of stations necessary, however, would be less owing to the scale being smaller, namely, 100 feet to 1 inch. In executing the work to be plotted on this scale, it becomes possible to take points at greater distances from a station, hence more ground is covered from each station; for it will be seen, that on the scale of 100 feet to 1 inch, one-fiftieth of an inch corresponds to 2 feet on the ground; this is as close as it would be necessary to locate contour points; the sights to the contour points, then, could be as long as 1,000 feet or perhaps a little longer, since it is possible in favourable light to read the rod at this distance to within 2 feet, and 1,000 feet is

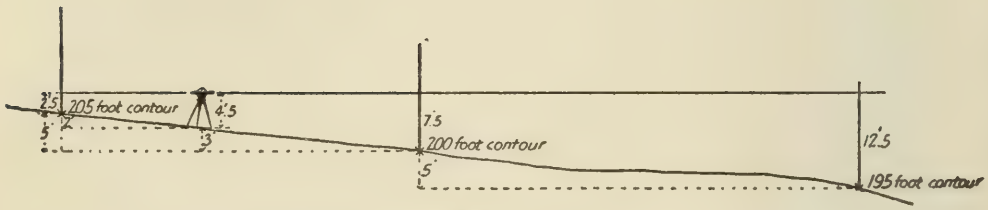


Diagram illustrating method of tracing 5 foot contours

DIAGRAM 3

Untimbered area shown thus

represented on the plan by a line 10 inches long which, as mentioned before, is conveniently plotted. It would be better to limit the length of sights to buildings, etc., to under this amount so that they would be located to the nearest foot, which corresponds to one one-hundredth of an inch on the scale used.

One station near the centre of the claim might be sufficient to obtain nearly all the topography of that claim. By putting the station up on a building or elevated tramway or any other point well above the ground, near the centre of the claim the road may be seen over the whole claim and all points taken from the one station.

Each station or set of stations, on one claim should be tied independently to the claim posts and lines of that claim.

The elevations are carried from one claim to the other by setting a hub in a convenient place near the side of the next adjoining claim so that it can be easily sighted to from a new station on that claim. The elevation of this hub is determined and its elevation used to determine the elevation of the new station in the next adjoining claim. This is repeated from claim to claim. These hubs correspond to the turning points in levelling. By setting two hubs near each other and determining the elevation of each, a check can be had on the elevation of the new station.

If for any reason the claims have not been properly surveyed or connected in any way, the best and most accurate method to connect the topographical work over the area covered by the claims is to establish a few points over the area by means of a triangulation from a measured base. These points would then be fixed points to which all the work can be tied. The different stations from which the topography is taken should be connected by traverses between these fixed points, so that their relative positions and elevations can be checked. The claim posts and lines being determined from these hubs which form traverses checked between tie points, accurate connected surveys of each of the claims, as well as all the topography over the area, are obtained in a very short time.

The positions of the triangulation points should be computed and plotted by Latitudes and Departures and oriented by determining the azimuth of one of the triangle sides, by observation on the sun or star. The elevations of these triangulation stations

might also be determined by vertical angulation, in order to form a check for the elevations carried through the traverses. This method is described in the previous paper mentioned.

Case 6.—If the claims have been properly surveyed and connected, each claim could be taken as described in *Case* 5, and the topography obtained by the method described for *Case* 3.

If, however, the claims have not been surveyed or connected, it would be necessary to resort to traverse control in order to obtain a set of fixed points to use as tie points, since a triangulation may not be feasible on account of the timber. These fixed points are best established by running two or three or more (depending on the extent of ground to be covered) closed traverses, and computing the positions of the stations on these by Latitudes and Departures. The circuits are balanced and any error in elevation distributed in its proper place. With these circuits as the framework, the rest of the work can then be proceeded with, using the stations on these circuits as the tie points.

It is not necessary to take up the last two cases as methods for these may be readily selected from what has been given.

The stadia has a great advantage over all other methods for locating buildings. A few examples will be given to illustrate some methods of locating buildings under different conditions. The diagrams explain themselves—the dotted lines represent distances measured by rodman.

Both corners visible from station.

Corner B not visible.

Point C in line with side.

Both corners not visible.

Points C and D in line with the two ends.

Both corners not visible.

C and D in line with ends.

Both corners not visible.

Point C on side, point D in line with side.

By using the Plane Table for filling in the detail, a great saving of time is accomplished, and better results in the sketching of the contours are gained. The use of the Plane Table is not described in this paper, as it was the intention only to describe those methods that could be employed with the instruments that are in more general use at mines.

SETTING OUT INCLINED SHAFT TIMBERS.

By D. J. Browne, Rossland, B.C.

One of the chief disadvantages of inclined shaft sinking for main winding purposes, when compared with vertical shaft sinking, is the difficulty of setting out, and preserving when set out, the alignment of the timbers. There are other problems to be considered, but this paper merely refers to the usual method of securing inclined shafts by sets or frames, consisting of two wall-plates, two end-pieces, and dividers and posts according to the number of compartments.

In theory the timbers of an inclined shaft should fulfil the following three conditions:—

(1). The end-pieces at any one end must all lie in one vertical plane;

(2). The wall-plates on any one side must all lie in one inclined plane at right angles to the above vertical plane;

(3). The frame as a whole must be perpendicular to both planes.

Upon consideration of these three rules, it will be observed that:—assuming, of course, the sets to be similar in all respects, except the posts or distance pieces, the length of which is regulated by the solidity of the ground,—opposite wall-plates are parallel, end-pieces also parallel, and all angles contained by adjacent timbers are right angles. In other words, the set is a three dimension rectangular figure.

In practice, the accuracy with which the timbers are set out to these conditions must be such as to ensure smooth running of the cages or skips, and to prevent the cables from cutting into the sides, always keeping the error down with a view to sinking to an indefinite depth. To carry this out, the engineer should pro-

vide the data to the timber men to enable them to work with their tools, which are usually square, plumbline and level. As their errors are usually cumulative, the engineer furthermore should check the timberman's work at intervals with his more accurate instruments. The frequency of this checking should depend upon the care with which they are doing their part.

The methods of the engineer are determined by the kind of instrument available, and by the size and dip of the shaft. For all but the deepest shafts, a $4\frac{1}{2}$ inch or 5 inch transit-theodolite, reading to one minute, by a good maker, is quite sufficiently accurate. It must be provided with a full vertical circle, an extensible tripod (or, better still, a bracket to screw into the timbers, or a stretcher-bar, in place of a tripod), a powerful telescope (at least 20 diameters, for sights of 700 or 800 feet. It is one of the few cases where a high power is required in a mine. If the transit will not sight an angle of depression as great as the inclination of the shaft to the horizontal, on account of the obstruction of the plate, some kind of auxiliary telescope is necessary.

In the case of a shaft already sunk some distance, the first business of the engineer is to determine the direction in azimuth, and inclination of its timbers, or, in other words, the two planes referred to above. This may be done by setting up the instrument at the collar, ascertaining the distances of the axes of the telescope from the nearest end-piece and wall-plate, sighting to a target placed in the same relative position with regard to the bottom set; and, by lining in nails on the end-pieces and wall-plates of each set, or each alternate set, or sighting a stadia rod held perpendicularly to them, ascertain the variation of the timbers all the way down. Or, if preferred to set up at the bottom, sight the collar, and off-set the timbers in the same way. In the draughting-room, a true length elevation and a cross-section is plotted, so that by a careful inspection of these, the best direction and inclination under the circumstances may be calculated for the continuation of the shaft. The former line is then set out by fixing two or more hubs in known wall-plates.

The various methods of laying off a set may be conveniently described as follows:—

(*a*). *By means of the side or top telescope in one compartment only.*

This method is simple in practice, and is quite satisfactory in small shafts, but when the length exceeds 16 feet, defects may appear in the compartment furthest away from that in which the engineer is working. It is therefore advisable, even in the case of three compartments, when an end compartment is used as a ladderway, to set out at the other end, so that the greatest error shall not come in a hoisting division.

Proceed as follows:—Set up the transit at a convenient distance above the timbers to be lined in (which have been loosely blocked in readiness) and over or under a point previously established, as already described. Back-sight to a similar point higher up, transit or reverse in azimuth, and turn off the inclination. Note what the distance should be from the centre of the telescope to the nearest end-piece or divider, and set out nails on the upper side of both wall-plates below at the same distance. Calculate from the vertical height of the instrument, the distance from the foot-wall-plate to the telescopic axis, and fix the target of a levelling-rod at this distance (or pencil a line on a wooden staff). In setting-out the pitch of the shaft, the rod is held on the foot-wall-plate in the line of sight, and the set wedged across until the line on the rod coincides with the horizontal cross-wire. Then for direction, the set is wedged over until the two nails are in the same vertical plane as the vertical cross-wire. The corners of the set are then tested with a square, and the wall-plates with a level, and corrected if necessary. The pitch and direction must be again checked, and the set permanently blocked without disturbing its adjustments.

(*b*). *By sighting laterally as well as across, with a telescope capable of movement in the inclined plane of the shaft.*

This method entails the use of a top telescope, which may be turned about a supplementary vertical axis:—*i.e.*, an axis at right angles to both axes of the main telescope. This condition is fulfilled by the Dunbar-Scott interchangeable auxiliary telescope, which is now a common feature of mining instruments. Used as a top telescope, it has a centre which may be screwed to a vertical pillar from the main telescope, and by means of two opposing screws, can be ranged in or out of the vertical plane of the latter. The Saegmuller solar telescope, made by many American firms, is another device answering this purpose. But both attachments

must be used with caution, particularly if there is no means of adjustment for plumb; which is often the case. But whatever instrument employed, a test in this respect should be made at the surface, by levelling up the main telescope, and checking the horizontal movement of the auxiliary by sights upon a levelling staff. If the results are unsatisfactory and impossible to correct, some other method must be used in the shaft.

Set up about midway in the shaft, and where an unobstructed view of both ends of the new set can be obtained. Bring the vertical wires of the two telescopes into the same plane, by bisecting some convenient mark; backsight and reverse, as before. Drive a nail on each wall-plate of the set to be lined in, at the same distance from the nearest corner or divider cut as the line of sight would be from the corresponding point in a correct set. Wedge the set over until both nails come under the vertical wire, and thus set out direction. Then turn off the inclination. Calculate the distance from the top telescope to the foot-wall, and set-out nails at this distance on each end-piece. Now, without altering the setting of the transit, move the top telescope about its supplementary vertical axis towards one end, and wedge the timbers across until the horizontal wire bisects the nail at that end. Do the same at the other end, and repeat the operation until the set is correct for pitch at both ends. Level up the foot-wall-plate. Readjust the top telescope into the vertical plane of the main, and again check the wall-plate nails. The set should now be in perfect alignment, for the corners are automatically squared, and by verifying this, an additional check on the accuracy of the whole work is obtained.

If use is made of the Dunbar-Scott device, which has only a limited angular range controlled by its opposing screws, care should be taken to set up sufficiently far away from the set to enable both end-pieces to be sighted. If, however, it is impracticable to do this, the pitch must be set off either by lining in nails on dividers in place of the end-pieces, or by sighting a rod held on the foot-wall-plate at right angles to the line of sight, and as near to the ends as possible.

This method is a satisfactory one for long shafts of four or five compartments, and takes rather less time than any of the others to execute. A clear view is afforded for sighting laterally

when the new set is put in at a distance of five or ten sets in advance of the rest, leaving intermediate sets to be inserted afterwards. This is the custom at some places.

(*c*). *By means of the main telescope, when the flatness of the shaft admits of its use.*

The conditions stated under this heading may be usefully subdivided into three special cases, as follows:—

(1). When it is possible to sight both wall-plates below;

(2). When the foot-wall is obscured by the horizontal limb of the transit, but the hanging-wall-plate can be seen, and

(3). When only the end-pieces can be sighted.*

In the first case it is obvious that the method described under (*a*) is applicable. The second and third, however, present a new problem, particularly the third, in which the difficulty lies not so much in setting out, as in carrying the line down the shaft. Backsights up, of course, may be taken by using an eye-piece prism, but the continuation of the line down can only be done by first putting a set into perfect alignment by the method stated below, and establishing the next point by measurement along a wall-plate. It must be carefully done, or serious errors will soon creep in. The only alternative is an inclined set-up at the collar, and this is even more unsatisfactory.

The lining in of the set is carried out by sighting obliquely on the upper and inner edge of each end-piece, the necessary horizontal and vertical setting of the transit being so calculated that when a nail, saw-cut, or other mark on the timbers in question, coincides with the intersection of the cross-wires, the alignment of the set is correct for both direction and pitch. Set up close to the foot-wall, and exactly midway between the ends, so as to save two sets of calculations. Set the vernier plate at zero, and with the bottom clamp loose, backsight for direction, clamp, plunge the telescope, and determine the distance from the telescope cross-axis to the foot-wall. On the upper and inner edges of the end-pieces below, set off marks at the same distance. Ascertain the slope distance from the horizontal axis of the instrument to the

* In theory, of course, if one sets up near enough, it is *always* possible to sight the wall-plates. But in practice, unless the set-up is on some such appliance as a stretcherbar, quite independent of the timbers, one must be at such a distance away as to be free from disturbing vibrations,—say fifteen to twenty feet.

top of the set below, measured along the pitch, and in the vertical plane of the shaft. This may be done by stretching a string tightly across the nearest set vertically above or below the instrument, noting the shortest distance to it, and deducting or adding this, as the case may be, from or to the distance between the sets.

Calculate the angles as follows:—Let l be the distance between the end-pieces, measured inside, d the slope distance from the transit to the set, φ the inclination of the shaft, and β and θ respectively, the horizontal deflection and vertical angles to be turned off (Fig. 1). Then $d \cos \varphi$ being the horizontal projection of d,

$$\tan\beta = \frac{\frac{l}{2}}{d \cos \varphi}$$

and for θ, the angle of depression,

$$\tan\theta = \frac{d \sin \varphi}{\frac{l}{2} \operatorname{cosec} \beta}$$

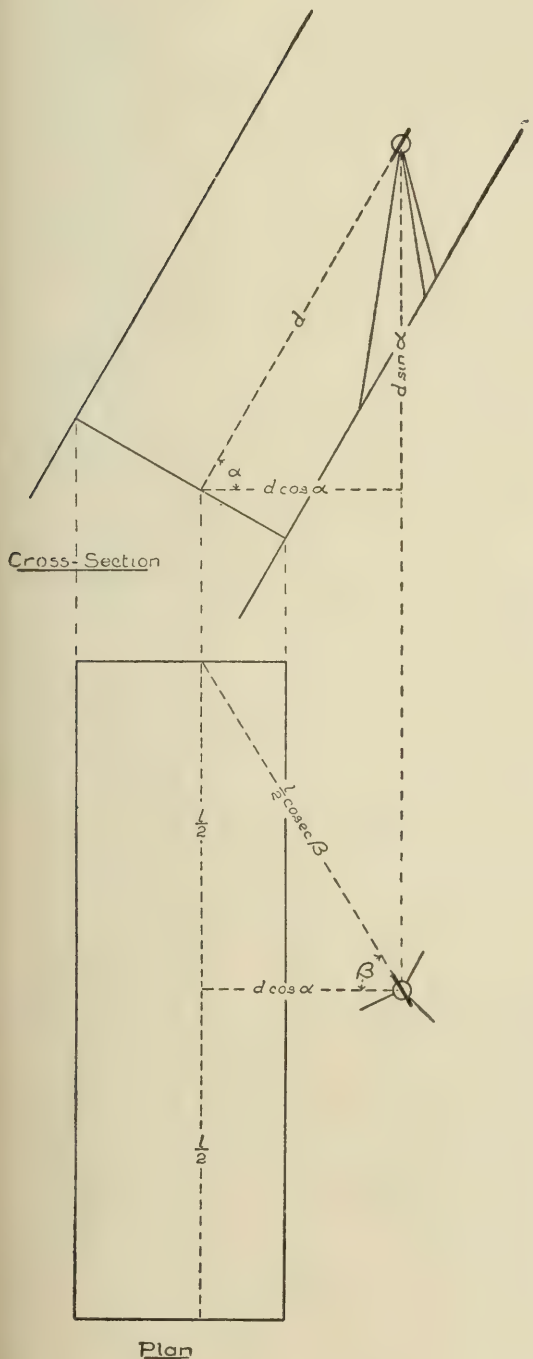
$$= \frac{2d \sin \varphi \sin \beta}{l}$$

$d \sin \varphi$ being the vertical projection of d, and $\frac{l}{2} \operatorname{cosec} \beta$ the horizontal projection of the line joining the instrument centre to the point on the end-piece.

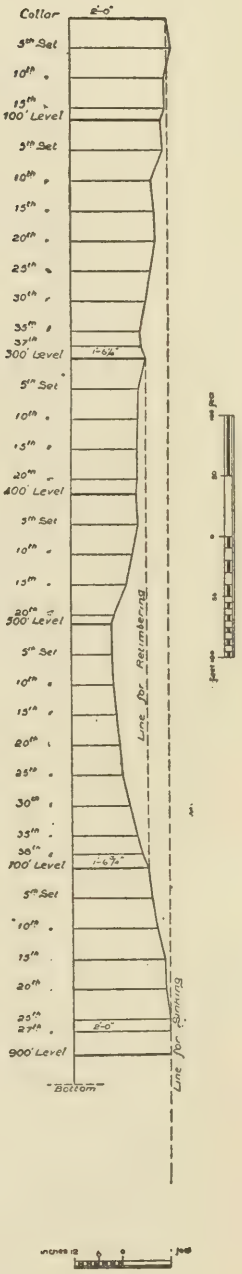
Set these angles for each end in turn. Wedge the set over and across until each mark is in its line of sight. Then square up the corners, and level the foot-wall-plate, and check the ends again. Time will be saved if blocking is placed immediately behind each end mark, so that when squaring up, it will act as a pivot about which the set will move, with little disturbance of its adjustments for line and pitch.

In conclusion it may be of interest to give a short account of recent experiences in re-timbering and sinking the main shaft at the Josie Mine, the property of Le Roi No. 2, Ltd., Rossland, B.C. This is a three-compartment shaft 14′ 5″ x 5′, measured inside the timbers, and 5′ from set to set. It dips at 74°–2′, a little to the west of north.

(Fig. 1)

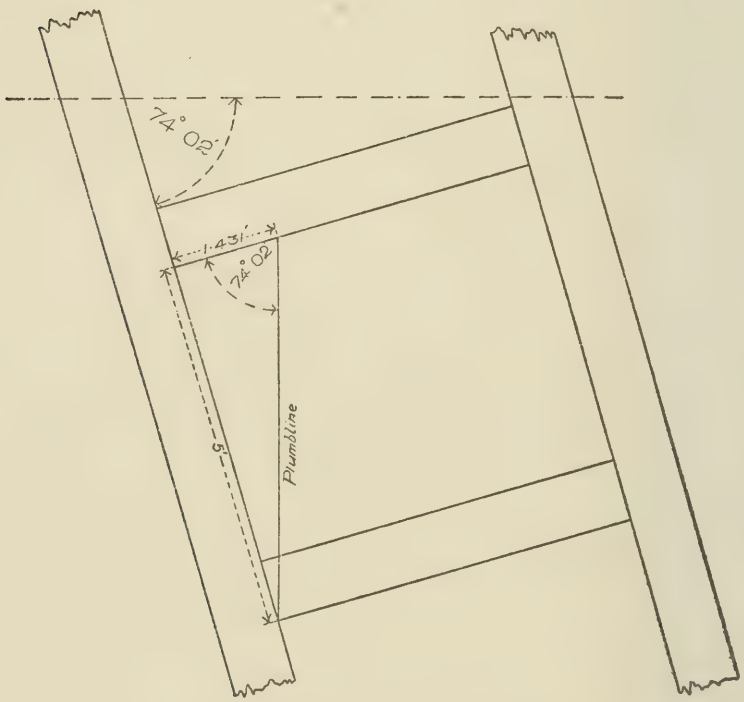

d
d sin α
α
d cos α
Cross-Section
½ cosec β
β
d cos α
Plan

(Fig. 2)


Collar
2'-0"
5th Set
10th "
15th "
100' Level
5th Set
10th "
15th "
20th "
25th "
30th "
35th "
37th "
300' Level
1'-6½"
5th Set
10th "
15th "
20th "
400' Level
5th Set
10th "
15th "
20th "
500' Level
5th Set
10th "
15th "
20th "
25th "
30th "
35th "
38th "
100' Level
1'-6½"
5th Set
10th "
15th "
20th "
25th "
27th "
2'-0"
900' Level
Bottom
Line for Retimbering
Line for Sinking

Early in the present year, some anxiety was occasioned by the decayed condition of about three hundred feet of timber, ranging between the 300 and 700 foot levels, and a comprehensive scheme of re-timbering was decided upon. Before starting work, however, an examination of the alignment of the sets was made, for this was known to be badly out; and as sinking was contemplated in the near future, it was determined to make some attempt

(Fig. 3.)



to put them right while there was an opportunity. A transit was set up in the 900 foot level station set (then within 25 feet of the bottom of the shaft) two feet from the east end-piece, and sighted to a nail in the hanging-wall of the collar set, also placed two feet from the east end-piece. At each station, all the way down, a nail in the hanging-wall was ranged into the same vertical plane. String was tightly stretched from nail to nail and off-sets were taken to the east corner by means of a rod, at intervals of five sets. From these data the diagram shown in Fig. 2, was drawn, representing a full length elevation from the foot-wall side; and in order to accentuate the variation of the timbers from the vertical plane sighted up, the horizontal dimensions were plotted to a

scale forty times greater than those measured up and down. An inspection of this drawing showed that perfect alignment could not be obtained without re-timbering the whole shaft from top to bottom. This was out of the question, both on account of the expense, and the complete shutdown of the mine that it entailed. So, observing that the errors at the 300 and 700 foot stations were about the same ($5\frac{3}{4}''$ and $5\frac{1}{4}''$, respectively), and that in between these two points lay all the rotten timber and greatest error, the management decided to re-timber and straighten out this part of the shaft only; and, when the time came for sinking, to take the line from the collar and 900 station sets,—a nearly parallel one.

Less attention was paid to the pitch, for a test made by sighting—a rod placed on the foot-wall-plate of each station set—showed the errors to be comparatively trivial, the worst being a hump of about 8 inches at the 700 foot level; and in sinking the inclination was taken from the same two sets as the direction.

In lining the first new set below the 900 foot level, the method adopted as being the most suitable, was that described under (*a*), a side telescope being used. As the sinking and timbering progressed, every fifth set was checked by the transit, and the error if any, determined. When this was found to be small—say within $\frac{3}{4}''$—the set was not corrected, but instead, the error was distributed over the next two or three sets, as they were put in, thus saving a good deal of time and trouble, without doing much harm. The timber gang usually kept within these limits. Their method of work was as follows:—Having loosely blocked the set in its place, its pitch was adjusted by dropping a plumbline from a mark on the bottom edge of each end-piece of the next set above, at a certain measured distance from the foot-wall corner (Fig. 3), and the foot-wall-plate was then wedged across, until its lower edge just touched the freely hanging plumbline. This measured distance, in the case of the Josie shaft, was 1.4306′, or 5 cotang 74° 02′, the distance from set to set being 5′, and the dip of the shaft 74° 2′. The correction of the set for direction was made by dropping the plumbline from a set above, and measuring from them to the ends. This done, the corners were squared and the wall-plates levelled.

With a good gang of four timbermen, the whole operation of putting a set in usually took about eight hours, when no special difficulties were encountered.

AN IMPROVED TYPE OF LANDING CHAIRS FOR MINING CAGES.

BY J. C. HOUSTON, Cobalt, Ont.

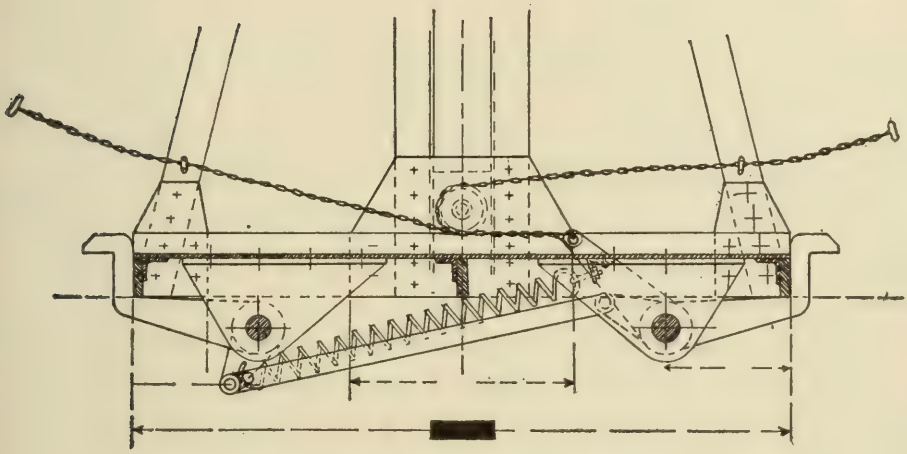
In ordinary hoisting practice at mines where a large tonnage output is a desideratum and speed a necessity, trouble and frequent delays are often occasioned in connection with the operation of cage chairs of the ordinary type. These delays are due to the neglect of the cage tender to swing the chairs clear of the cage, when signalling the hoist man to drop the cage to a lower level. The cage in consequence is allowed to drop on the chairs at speed, thereby wrecking them and sometimes the set of timbers to which they are attached. Using the common type it is also necessary to install a separate set of chairs at each level. This entails the partial cutting away of the station set and occasionally also necessitates the installation of auxiliary timbers to support it. The items of time and costs have also to be reckoned.

With the improved chairs as designed by the writer for some of the mines in the Cobalt camp most of the objections to the ordinary type are overcome. The chairs are permanently attached to the cage, of which they form a part and it is only necessary to have the one set, no matter how many levels may be in use. They require no auxiliary apparatus for their use, no cutting away of timbers and if it be necessary to repair timber or guides at any intermediate point in the shaft, the cage may be landed on any set of timbers for that purpose, since the chairs may be operated from the cage or from either side of the shaft.

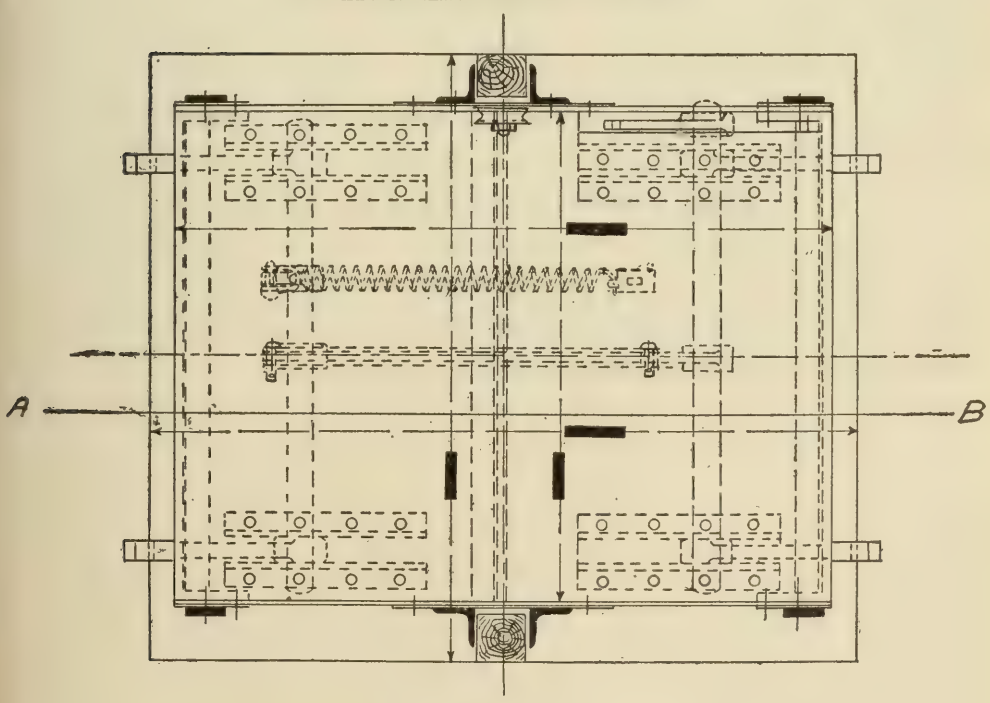
As constructed, the apparatus consists of four chairs, one at each corner of the cage bottom, swung on two jack shafts that rotate in bracket bearings underneath the floor of the cage, which latter is made of three-eighth sheet steel. The two shafts are

IMPROVED FORM OF LANDING CHAIRS
FOR MINE CAGE

Jos. C. Houston
Cobalt
Ont.



Section Along Line A-B



Plan.

connected up with levers and connecting, link, so that they move together but in opposite directions. A lever projecting through a slot in the floor of and to one side of the cage, is keyed to an end of one of the shafts. To the end of this lever is attached two pieces of three-sixteenth chain, one of which leads over a pulley fastened to the verticle angle bars, and back through an eye bolt in the diagonal brace and ending in a pull or handle. The other passes directly through an eye bolt on the opposite brace and is similarly "rigged." The cage tender catches the pull as the cage is slowing up to land and pulls it in a direction towards himself. This operation, acting through the levers and jack shaft, swings the chairs out simultaneously and the cage comes to rest on them flush with the landing. This may be effected from either side of the shaft or while riding on the cage.

The chairs are not rigidly keyed to the shaft, but have a radial slot cut in the hub, provided with a one-half inch pin that is fastened solidly in the shaft, and allowing the chair to move a one quarter of a revolution, independently of the shaft. This provision prevents the fouling of the chains. In operation, as soon as the hoist men removes the weight of the load from the chairs and before the chairs have moved, the coil spring (as shown in accompanying diagram) instantly forces the jack-shafts and chains to the set position, permitting the chairs by their own weight to drop full and swing beneath the floor of the cage out of the way.

Several of this type of chairs have now been in use in the Cobalt camp for two or three years and have not only given complete satisfaction in operation, but have proved to be economical both in respect of outlay and of time.

THE PROTECTION OF MINE TIMBERS FROM FUNGUS.

By JOHN MACOUN, Dominion Naturalist, Ottawa, Ont.

There is nothing connected with the working of mines of greater importance than the protection of mine timber from rot. It is a matter concerning which little is commonly known. When so much depends upon the strength and stability of mine props, it is remarkable that at the present time practically no efforts have been made to lengthen the life of mine timber. Of the most destructive fungi, even science has not much knowledge. Many of them belong to the genera *Merulius* and *Polyporus*. *Merulius* is the commonest form of dry-rot and attacks chiefly pine and fir. The name dry-rot carries with it a wrong impression, as dry wood is never attacked; damp, unventilated situations being most favourable to the growth of dry-rots. Well ventilated mines are to a very considerable degree free from fungus growths. In both the genera referred to—*Merulius and Polyporus* —the rot is caused by the mycelium which penetrate the wood, thus destroying it. The fungi themselves are often of large size, but the actual damage is done by the thread-like mycelium. The molds which are so frequently seen on mine timbers, most of which are of the family *Hyphomycete*, are not really injurious to the timbers; their natural habitat is on the surface of wet wood and when the conditions are suitable they grow in mines, just as they do in our cellars, without any direct injury to more than the surface of the wood. It has been generally assumed that the treatment that has proved so efficacious in preserving railway ties, telegraph poles and fence posts might be used in mines; but this is not the case, and saturating the wood with creosote is not only expensive but is not a sure preventive. Apart entirely from the great expense these methods entail, the conditions are so vastly different that it is more than doubtful whether the results of open air experiments are of much value when applied to deep mines.

Acting under instructions from the Director of the Geological Survey, I visited several mines in the Rossland district in September, 1908, and was astonished to find that nothing whatever was being done there to protect mine timber from rot; and from what I have been able to learn from men familiar with Canadian coal mines, the conditions in these mines are even worse than they are in any other kind of mine because—as I shall explain later—the timbers now in place in these mines may be preserved at a very small cost.

During the last thirty years I have spent many seasons on both the Atlantic and Pacific coasts, and the difference between the condition of the drift wood on these coasts and that found along our interior lakes attracted my attention many years ago. Members of the Geological Survey staff inform me, moreover, that the wood found along the shores of Hudson Bay, the MacKenzie delta and Behring Sea is of the same character as that which has come under my own observation. Speaking generally, all wood found on the sea-shore is free from fungus rot, while that found along fresh-water streams or lakes begins to rot within a year or two after it is left on the shore. The inference is plain. Some constituent in the salt water protects the wood; and when we remember that all fungi are produced from spores —microscopic in size—it is evident that if these spores can be prevented from developing, fungus rot is impossible. Since my return from the field last autumn the Director of the Geological Survey has shown me a description of what is known as the Henry Aiken method of treating timber for use in mines. A full account of Mr. Aiken's treatment may be found in the Summary Report of the Geological Survey for 1908, and only the briefest summary need be given here.

In this process the timber is soaked in water, raised to a temperature of from 190° to 200° Fahr., and contains enough common salt to form a thoroughly saturated solution. The timber should be free from bark, fairly well seasoned and thoroughly dry. Tests made in many British collieries have proved conclusively that this treatment is in every way a satisfactory one. In one mine the timbers, after being in place five years, were perfectly sound and in another they had shown no sign of rot at the end of six years. What is even more noteworthy is

an experiment made in Fifeshire. Two pieces of ordinary fir, $3\frac{1}{2}$ inches in diameter and three feet long, both weighing ten pounds, before being treated, were selected. One of the pieces was treated by the salt process and the other not. After being treated it weighed 12 pounds. Both were taken underground and placed in a return air-course and after eleven months were examined and re-weighed. The untreated timber then weighed only 5 pounds whereas the treated wood weighed 12 pounds, or exactly the same weight as when it was put in. They were replaced in the mine and allowed to remain eleven months longer, with the result that the untreated timber weighed 6 pounds and the treated timber weighed $11\frac{3}{4}$ pounds. They were again replaced in the mine, and after an exposure of three years they were examined and while the treated piece was sound the untreated one was decayed. Such evidence as this must be considered as conclusive, and as the salt water treatment is inexpensive, there seems to be no good reason why all mine timbers should not in future be treated in this way. Timbers already in place might from time to time be sprayed with salt water for, while such treatment could not be expected to prove as efficacious as if the wood were soaked in brine, still it is reasonably certain that few fungus spores could develop on wood that was so treated. In coal mines where spraying is systematically done for the purpose of preventing coal dust explosions the addition of salt to the water used would entail very little extra expense. What is certain is, that when the greatly enhanced price of timber in recent years is taken into consideration, the cost of treating mine timbers with salt is insignificant as compared with the money that would be saved.

NITRO-STARCH DYNAMITE, ITS MANUFACTURE AND PRACTICAL USE IN MINING AND QUARRYING.

By A. Mosco Vici, Montreal.

In presenting a paper on this subject it is proposed to indicate briefly the advantages of a new explosive, known as Nitro-Starch, and to compare it with the older known explosives, viz.:— nitro-glycerin, ammonium-nitrates, picrates, etc.

One of the main characteristics of nitro-starch is its non-freezing property. As is well known, nitro-glycerin dynamite freezes at 44-46°F., *i.e.*, the liquid high explosive (which is pure nitro-glycerin) crystallizes out in its absorbent at this temperature. Now in the case of nitro-starch, the high explosive is solid, and when mixed with a solid absorbent is unaffected by cold. This, therefore, does away with the necessity of thawing, which is, of course, one of the most dangerous factors in the use of nitro-glycerin; in fact, it is said to be the cause of over 80% of the accidents occurring from the use of dynamite.

Another, and even greater advantage, is that nitro-starch in the pure form, or graded dynamite, by the addition of suitable absorbents, either in free-running or plastic conditions, may be shipped and handled with safety. It cannot be detonated by heat alone, but requires the effect of the fulminating cap to cause detonation. Thus should a carload of this explosive be ignited by any cause, as might for example happen in the wreck of a train, it would merely burn away quietly without exploding. Even in the plastic condition, the safety feature is absolutely certain, for the reason that the liquid nitro compound employed to render the nitro-starch plastic, and which will be referred to later on, has exactly the same safety property as the nitro-starch itself. This safety feature has been so thoroughly demonstrated that one

of the largest railway companies in the United States, the Delaware, Lackawanna & Western railway, has undertaken to transport nitro-starch plastic powder, although refusing all others, since the date of an accident which occurred some years ago on their line from the explosion of nitro-glycerin dynamite, and which resulted in the company being called on to pay very heavy damages.

RESULTS OF PRACTICAL TEST.

45% *nitro-starch dynamite tested at Taylor Mines, Delaware, Lackawanna & Western Coal Mines at Scranton, Pa.:*—Hole 6 feet deep drilled horizontally; coal 7 feet at breast; 8½ sticks of dynamite 1¼″ x 8″ size were used.

The blast shattered a mass of coal which was 7½ feet long, thus giving 1½ feet more than the size of the hole.

The composition of this dynamite was as follows:—

18% Nitro-starch 22% Nitro-glycol	}	40%
Sodium nitrate Resin mixture Wood pulp	}	Absorbent

The proportions of combustion were 2.7 sodium nitrate to 1 carbonaceous matter.

Attention is here directed to one of the main features which was approved of by all the superintendents of the Lackawanna coal mines present when this test was made, namely, that thirty seconds after the charge of dynamite was fired a return was immediately possible to the breast and the miners were ready to load the wagonettes which were sent to the surface (this on account of the absence of smoke); whereas after a blast of ordinary dynamite the miners could not safely return to work for from ten to fifteen minutes. This saving of time is not only advantageous to the operators, but also to the miners who get paid by the ton.

60% *nitro-starch dynamite tested at Franklin Furnace Quarries, Franklin Furnace, N.J.*—This is a limestone quarry, the rock being very hard. Nitro-glycerin gelatine dynamite has been used for upwards of twenty years. The holes drilled here were 18 feet deep. Tests were conducted during the winter season

with nitro-starch plastic powder. The quantity of material dislodged by blasting a series of six holes, charging and exploding the charge by electricity, was over six hundred tons of limestone. This result is considered to be very satisfactory.

Another practical test made to illustrate the efficiency of this high explosive, was at a limestone quarry at Swatara, Pa., near a station between Reading and Harrisburg on the P. & R. railway. The holes were drilled at a depth of 45 feet and were 6 inches in diameter. Two and a half tons of nitro-starch dynamite, equal to 45% strength, were used to a charge. The blasts dislodged 22,000 tons of limestone, ready for shipment. This is equivalent to one quarter of a pound of dynamite per ton of limestone dislodged.

In a test conducted at Glen Mills, Pa., a station between Philadelphia and Pottsville, on the Pennsylvania railroad, where a trap rock was quarried, a 40% nitro-starch dynamite was used in the proportion of three-quarters of a pound of dynamite per ton of rock; whereas using ordinary nitro-glycerin dynamite, one and an eighth to one and a quarter pounds were required to secure efficient results.

These are a few of many instances proving the efficiency and superiority of this new high explosive as compared with the nitro-glycerin dynamite.

Manufacture and Use.

Nitro-starch, or zyloidin, as so named by its discoverer, was first prepared by dissolving dry starch in concentrated nitric acid, precipitating the nitro product by the addition of water, and neutralizing any free acid with a solution of sodium carbonate. This product consisted of the nitro-starches of various degrees of nitration, very unstable, and totally unfitted for industrial purposes. Further progress was made, however, by nitrating the starch in the manner described above, and after neutralizing the free acid, boiling the product in a very dilute alkaline solution, by this means removing much of the unstable matter. The product, however, was not satisfactory. Later, Nobels manufactured nitro-starch in considerable quantities by the process of dissolving the starch in nitric acid and precipitating the nitro product in the waste acids obtained from the nitration of glycerin.

the nitro-starch obtained in this way was then neutralized in the usual manner, and finally milled under edge runners with a 5% sodium carbonate solution, to which was added one per cent. of aniline. But this method was not apparently an improvement over former processes. The aniline was relied upon to preserve the stability of the nitro-starch, but the use of all such agents should be avoided.

Many investigators appear to be under the impression that the instability of nitro-starch is caused by the presence of free acid, and the complete removal of this acid should render the nitro-starch stable. They also hold that the bursting of the starch granule during nitration resulted in a physical condition of the nitro product of such a character that it is impossible to eliminate the traces of free acid, even by prolonged boiling. Following along these lines, a process was suggested for the nitration of the starch in a mixture of nitric and sulphuric acids at a temperature below 4°C.; at this temperature the original form of the starch granule is preserved, and if nitro-starch in this way obtained be well stabilized, the product will undoubtedly, and for a considerable time, give very fair heat tests. But the trouble is not removed, it is only delayed. Investigations carried on for over a year proved conclusively that a chemical action is in progress within the nitro-starch granule which finally bursts, apparently from spontaneous decomposition. In reality this is a progressive decomposition from the start, not observable, however, for a long period, since the dense coating over that portion of the substance which is subject to decomposition, hides the action from notice.

All results secured from investigations along these lines demonstrated beyond any doubt that in order to procure a stable form of nitro-starch, the starch granule must first of all be completely disintegrated. This is of paramount importance.

While it is true that the presence of minute quantities of free acid, or very low nitrates of starch will ensure the instability of the product, it is a very easy matter to eliminate these impurities by boiling the product in a very weak alkaline solution, great care being taken to add the reagent in very small quantities at a time, avoiding any excess of the reagent; otherwise the higher nitrates of starch are sure to suffer decomposition, for it must be remembered that all of the nitro-starches are more or less decomposed by boiling alkaline solutions.

By very careful manipulation, however, the nitro-starch may be stabilized by sodium hydrate as the reagent, without in any way affecting the required product. If these impurities constituted the only drawbacks to be overcome, there would be little difficulty; but unfortunately there is a far more serious factor to be reckoned with than either of those above mentioned.

When the best description of starch is nitrated, there are present in the product, free acid, some low nitrates, and a peculiar compound which has a high degree of nitration, and upon which the boiling water apparently has no action. It is closely allied with the true nitro-starch. It is this substance which has made all the nitro-starches very uncertain as regards stability, and has puzzled the cleverest investigators. For some time it was considered impossible to discover a reagent that would break up this impurity without injuriously affecting the final product. Now, however, such a reagent has been found, and by its use the undesired nitro compound may be separated from the true nitro-starch.

It follows, however, that such methods of stabilizing as described above, must result in an unnecessary loss of nitric acid and that the proper course to pursue is to strike at the root of the trouble, and eliminate from the starch that body which produces this troublesome nitro compound. To this end experiments with the starch were conducted and a method finally discovered by which the starch may be treated and the peculiar substance removed. This modified starch has properties differing widely from the ordinary starch. It is much less hygroscopic. The principal hygroscopic property of ordinary starch seems to be centred in this extract. This material, in an anhydrous condition, has only been obtained with the greatest difficulty.

The nitrated extract is exceedingly hygroscopic, and the well known hygroscopic property of nitro-starch may very reasonably be attributed to the presence of this material. Some of this material has been under observation for some time and although when freshly prepared it will stand the heat test well, it gradually undergoes decomposition.

Having now obtained the starch in the desired form, the nitration process requires to be considered. By using the modified starch and carefully selecting the acid mixtures, it is quite possible

to obtain in the product any predetermined percentage of nitrogen. It is possible to estimate the nitrogen content to within .1%. Nitro-starch can also be used in the manufacture of smokeless powder.

If the nitro starch is required for smokeless powder, and the nitrogen content be from 12% to 13%, the quantity of mixed acids employed should be in the ratio of 3.9 parts of acids to one part of the anhydrous starch.

The Nitration Process.

The starch is injected beneath the surface of the acids by an improved form of injector, at an air pressure of not less than 100 pounds to the square inch, the air having been previously thoroughly dried. The mixture is in the form of a thin paste, which is run into a large quantity of water with brisk air agitation. One washing with a solution of carbonate of soda is sufficient to neutralize the free acid and then the nitro-starch is then allowed to settle, which operation takes about thirty minutes. The washing water is now run off and a fresh supply added, the nitro-starch is rapidly cut from the bottom of the washing tank by means of compressed air, and the stabilizing agent added very slowly while the water is gradually brought to the boiling point. The boiling process as a rule occupies about one hour, and at the end of that time the nitro-starch will be found to have a slight orange tint. Before this tint becomes pronounced the addition of the stabilizing reagent must be stopped, as this celeration is a very delicate indication that the reagent has decomposed the impurities and is acting on the true nitro-starch. The nitro-starch is again allowed to settle and a last washing given with cold water, when the product is ready to be dried. The pasty mast is now pumped over a film dryer. The nitro-starch obtained from this contains about 10% of water. The final drying is effected on canvas trays.

The nitro-starch so prepared has the following properties:—

Percentage of Nitrogen	13.2%
Soluble in Ether Alcohol	71.0
Soluble in Acetone	98.3
Combustion at 170°C.	

Nitro-starch is eminently adapted for the preparation of dynamite. The higher nitrates of starch have a velocity of detonation very nearly equal to that of nitro-glycerin, and by combination with such mixtures as sodium nitrate and resin, wood pulp or other carbonaceous materials form very powerful dynamites. Such mixtures will detonate with the ordinary fulminate cap, even when the nitro-starch is in the proportion of 20% of the whole.

One of the great advantages of nitro-starch as a high explosive base for dynamites, is that the ingredients of the mixture may be proportioned so as to give perfect combustion, a condition that does not obtain in the manufacture of nitro-glycerin dynamites, since the mixture in this latter instance must be regulated to hold the nitro-glycerin in the proper condition to ensure detonation.

Nitro-starch added to an active mixture is a free running powder and if properly prepared is fumeless when exploded by heat alone. Detonation cannot be brought about at any temperature and, of course, it is non-freezing. The great difficulty, however, has been the free running character of the mixtures and although many solutions have been used to render the nitro-starch dynamite slightly plastic, it could not be used with the same disregard to the action of water as in the case of nitro-glycerin dynamite, which is oily and therefore resists the action of water. Hence notwithstanding the many points of merit possessed by the nitro-starch dynamites, they failed to become popular on account of this drawback.

The rendering of the free running nitro starch powders plastic, and the formation of gelatin from nitro-starch is attended with many difficulties. It is quite out of the question to use any inert or inexplosive liquid for this purpose, for the reason that the addition of such materials reduces enormously the velocity of detonation of the nitro-starch and detracts from its value as a blasting agent. Again, any liquid explosive selected for the compounding of the nitro-starch must have very little, if any, solvent action on it and it must possess a velocity of detonation approaching, if not equal to that of the nitro-starch, and above all it must be non-freezing and fumeless. Should the liquid have any decided solvent action the nitro-starch, then all the detonating property of this material is lost and it enters the class of progressive combustion explosives. These are the conditions to be observed in the production of a plastic and water resisting nitro-starch dyna-

mite; at least, if the product is to have all the points of merit that will enable it to supplant in every instance nitro-glycerin dynamites.

To find such a liquid explosive, the writer has investigated the properties of every known liquid explosive, none of which would answer the purpose. At last among the series of alcohols, one was found that has exactly the properties required. That is to say, it can be cheaply prepared by electrolysis, has a specific gravity of 1.2, is capable of nitration from 11% to over 16%, forming an oily liquid, having properties very nearly akin to those of nitro-starch, excepting in the physical point, of course. This is the glycol. It is exceedingly stable, cannot be detonated at any temperature, and will not congeal at any ordinary temperature.

With nitro-starch and this explosive liquid as bases upon which to work, every type of dynamite may be prepared, and the products have all the advantages of nitro-glycerin dynamite with, of course, none of the disadvantages of this latter material.

CONCLUSIONS.

The writer believes, in conclusion, that nitro-starch dynamite will ere long be manufactured in Canada on a commercial scale. He has personally manufactured the material, and has tested it at several mines and quarries proving conclusively its efficiency as well as its great safety.

The advantages *en resumé* compared with nitro-glycerin are:—

1.—Process of manufacture free of all danger.
2.—Detonates perfectly.
3.—Does not freeze.
4.—Produces no injurious fumes when exploded.
5.—Perfectly stable in all climates.
6.—Being solid, dynamite made with nitro-starch does not change in physical condition.
7.—Cannot be exploded by heat or concussion.

If this material were generally used, the dangers in mining would be very considerably minimized, since nitro-starch does not require to be thawed out in cold weather, and is insensitive to shocks occasioned by steel bars or any other external agents. It is therefore an ideal explosive for use in mines or on railway construction work.

DEFICIENCIES IN CANADIAN MINING LAWS— A PLEA FOR IMPROVEMENT AND UNIFICATION.

By H. Mortimer-Lamb, Montreal.

(Annual Meeting, Toronto, 1910).

In the present paper it is proposed to elaborate on the theme discussed by Mr. Eugene Coste, in a communication to the Institute in 1904, and published in Vol. VII. of the Journal under the title of "Suggested Improvements to the Mining Laws of Canada."*

For many years past the Institute has advocated the desirability of improving and unifying the mining laws of the Dominion and those of the several Canadian Provinces. Uniformity or standardization in this respect would, it is believed, be attended with many and quite obvious advantages. It would have the effect undoubtedly of stimulating exploration; it would, in general, simplify conditions under which mining is carried on, and would consequently tend to encourage the investment of capital, as well as facilitate the operation of mines. Again—and this, perhaps, is the major consideration—the acceptance of the idea would necessitate a most careful and comprehensive survey of the situation. The broad question of mining law in its relation to industry would require to be conscientiously studied; and this investigation and enquiry should result in the adoption of a uniform law for Canada, right and just in principle, and relieved of those objectionable features that may now be found in all existing codes.

It is, of course, unwise to shut one's eyes to the fact that the problem is beset with extraordinary difficulties, not the least of

* Journal C. M. I., Vol. VII (1904), P. 450-479

which is to satisfy those who are responsible for the making of the laws that any such project as that proposed is either necessary or expedient. But public opinion is a potent factor in bringing about any reform; and it is, therefore, clearly the duty and function of the Institute to educate public opinion to a right way of thinking. Another difficulty, but, it is hoped, not an insuperable one, is to secure unanimity of opinion as to what would constitute an ideal mining law. The reference here, of course, is to fundamentals, and not to matters of detail. In examining the mining laws of the several provinces, one observes that they more or less readily group themselves into two classes. In the Maritime Provinces of Nova Scotia and New Brunswick the principle of leasehold obtains; while, also, on all minerals won royalties are imposed. On the hand, the mining laws of the Dominion, and of the Provinces of Quebec, Ontario, and British Columbia, in respect of metalliferous mines are practically identical in principle. That principle is the promotion of individual ownership by granting titles in fee upon the performance of certain required conditions. The reconciliation of these differences, or rather the adoption of one or the other basic principle in the framing of a general mining law, is consequently imperative before any detailed scheme can be considered.

The law of Nova Scotia and New Brunswick in respect of the granting of titles to mineral lands follows British precedent. That of Quebec is based to some extent on ancient French law; while in British Columbia and Ontario, the United States' principle governing the disposition of lands has been adopted. At first sight it would appear that since conditions in the United States are closely analagous to those obtaining in Canada, a law that had proved effective and workable in the former country would prove equally effective and workable in the latter. It has yet to be proved, however, that the United States' policy of granting patents in fee has been, or in its ultimate effect will be, productive of the best results; while experience of this practice in British Columbia and Ontario has been that it conduces to the "tying up" of large areas of mineral land that might otherwise be profitably exploited. In other words, the principle involving the alienation of lands from the Crown or State tends to encourage the speculative acquisition and holding of territory rather than to its develop-

ment and utilization, unless, of course, conditions for working happen to be peculiarly favourable. Manifestly a law having such a tendency is neither sound nor desirable, and unless it can be shown that it possesses advantages considerably out-weighing this serious imperfection, it is clearly the duty of Canadian legislators to consider a possible change of policy. But the United States is not the only country whose conditions approximate and compare with those in our own. Australia, for example, may be taken as affording an equally clear analogue; and the evidence here completely refutes any contention that the principle of freehold tenure as recognized in the United States is the right one, more especially in relation to the successful development and economic utilization of the mineral resources of a new country. The discovery of rich gold fields in the United States and in Australia was nearly contemporaneous. In neither country was the mining law on a definite basis, and the miners themselves in each case were obliged to draw up and enforce regulations for the protection of individual interests. These regulations primarily represented the principle that development should be a condition of possession. In 1866, however, the United States Mining Act, which in essentials does not differ materially from the present law, was passed. This Act ignored the principle of continuous development, but provided instead as a preliminary condition to the issue of a patent the performance of a merely nominal representation or "assessment work," spread over a short period of years. The Act also recognized the so-called "law of the apex," which has since led to so much bitter contention and costly litigation. Practically the same course was followed by the Governments of the Australian States, but the defects of the system were almost at once discerned and a new policy was inaugurated. As to the result of the change, it may, perhaps, be most graphically illustrated by quoting from a speech delivered before the Conservation Committee of the United States, by Mr. A. C. Veatch, of the United States Geological Survey, who was commissioned to investigate the mining laws of the Australian Commonwealth. He remarks, "The recent mining enactments of all the Australasian states, regardless of political complexion, are based on the policy of mineral leasehold. Not only do the political parties of Australia to-day heartily endorse this policy, but it represents a gradual evolution

from the principle of freehold, through stages varying somewhat in different states.

"The mining laws of all these states require continuous development, the enforcement of which is incompatible with the state of freehold. Development as a condition of possession was early recognized in mining practice in the United States; but the annual assessment work required by the present mining law fails to accomplish the continuous development which is requisite to a proper utilization of the mineral resources of the country. On this account the consideration of the extent to which the leasing policy succeeds in securing such development becomes of vital interest.

"In Western Australia the development of the mineral lands laws has been particularly simple. At the time of the first mineral discoveries in 1842, mineral lands were sold under the same conditions as agricultural lands. Later the purchase price was fixed and the option of lease provided. After the gold finds of 1885, the abandonment of the principle of sale became a State policy, and in 1898 provision was made that land grants should contain a reservation of all minerals. Thus, in Western Australia the system of leasehold and claimhold on the conditions of *bona-fide* development came at a time most opportune for the test of practice. For the five years comprising 1881-1885 the average annual mineral production was less than 9,000 pounds sterling, while for the past five years the annual output has exceeded 8,000,000 pounds sterling. Not only was the law subjected to this practical test of great expansion in the mining industry, but an investigation by a commission on mining showed that throughout the gold fields the verdict was overwhelmingly in favour of leasing."

It may be argued, however, that the freehold system has obtained for too long a time in Central and Western Canada to render a change of policy now desirable. But in reply to this Mr. Veatch instances the case of South Australia, where the alienation of minerals had been carried even further than in the United States, and yet the principle of leasehold has since been developed with the most surprising results In this connection he states that in South Australia the alienation of minerals had been carried further even than in the United States, yet here, too, the principle of leasehold has developed and been fully tested; and points out that the

history of the mining law of this country is of especial interest to Americans, since it shows the practicability of introducing a system of government leasehold after important mining properties had passed into private ownership. There has resulted, he adds, a surprising unanimity of opinion in favour of government leaseholds for all minerals: "Mining engineers, operators, and capitalists unite in asserting that mining development is promoted more by leasehold than by freehold. The leaders of the several political parties agree that the matter of government leasehold is not a party question. It is important to note that the mining laws of both Western Australia and South Australia were developed under Conservative or Tory Governments, and while a Labour Government has been in power for some years in South Australia, these mining laws cannot be characterized as radical labour legislation. They are, in fact, non-partisan enactments which antedate the present supremacy of the Labour party."

But even in the United States some change in sentiment is apparently taking place, for in a letter to the writer, Mr. R. A. Ballinger, Secretary of the Interior at Washington, observes that "lately the tendency, with respect to the fuel minerals, such as coal, oil, and natural gas, has been in favour of the retention in the Government of the fee title to these deposits, and their control, disposition, and production under a leasing system, permitting governmental control in their development and in the prices charged by the lessees to the consuming public; and to that end I have prepared, and, with the approval of the President, submitted to Congress drafts of suggested bills to accomplish this end."

It should be mentioned, however, that the significance of this statement is to some extent modified by a succeeding paragraph in the letter from which the above quotation is taken, explaining that "the reason for legislation of the character suggested as to the fuels is absent in connection with the precious metals, and no suggestion has been made by me as to any change of the existing law governing their disposition."

But this allusion is, perhaps, somewhat beside the point, for while we may learn from the experience of other countries, the exigencies of our own case must necessarily control and govern the consideration of any question of the kind.

It is, then, pertinent to enquire first whether in recent years the expansion of the mineral industry has been commensurate with the importance of the known and potential mineral resources of the country? However optimistic one's vision may be, the actual facts of the case certainly do not admit of a too close analysis. During the last five years all the conditions have been conducive to rapid growth and industrial ameliorations. Industries and interests, other than mining, however, have been relatively far more sensitive to these extraneous influences. Taking the annual statistics of mineral production as published by the Federal Department of Mines as a part indication of progress, the best that may be said on the basis of this evidence is that a modest but steady growth has been maintained; and this, notwithstanding the important contributions of late to the aggregate mineral yield as the result of the discovery and development of rich virgin territory.

To particularize, in British Columbia, progress has been almost limited to the natural growth of long established industries. During the last ten years there have been no new finds, no developments of really first rate importance. Prospecting, for a short time, so active, has practically ceased.

In Alberta, mining activity, which has assumed considerable proportions has been confined to coal mining. But here, although the regulations contain many most objectionable features, the basic principle is leasehold tenure, conditional on development, and consequently the argument against the principle of freehold does not apply. There is, however, no prospecting for or development of other minerals, and the conditions are such that although in Alberta the indications of the occurrence of oil are pre-eminently favourable, the law is such that capital has been repeatedly discouraged from carrying on investigation, and at the present time no attempt is being made to develop this field.

In Ontario, the phenomenally rich discoveries in Cobalt and elsewhere have for the time being provoked activity and diverted attention from the imperfection of the mining law; while the stagnation of mining, outside a very limited but unique mineral area in Quebec—which province, on the testimony of geologists, we are taught to believe is potentially an exceptionally rich region—can only be attributable to the unsound and defective principle

on which the mining law of that Province is based. It is but just, however, to add that the amendments introduced in 1909 indicate a praiseworthy and conscientious attempt to improve on the former regulations and system. Since the principle of freehold is inherently unsound it follows that the regulations made in conformity with this general policy must necessarily be fundamentally defective. Thus in the Dominion, British Columbia and Ontario law respecting the acquisition of metalliferous mines we have the provision, for example, requiring "discovery," or in the case of Ontario, "valuable discovery" as a condition of right to locate. In British Columbia this clause in the Act is to all intents and purposes, meaningless, since the courts have ruled that any rock *in situ* constitutes "discovery"; in Ontario the law in this respect is now a dead letter; but there can be no doubt that during the time it was observed it worked in many instances hardship and injustice on *bona fide* locators of claims; moreover it imposed an unfair responsibility on officials who were vested with arbitrary authority to adjudicate on the matter, and it served to encourage wildcat promotion by, in effect, bracketting all claims that had passed the test of Government inspection as valuable locations—between which term and "mine" the public does not differentiate. When inspection is not provided, a "discovery" clause is merely an incentive to false swearing or fraudulent misrepresentation. It is not proposed, however, in the present paper to enter into a discussion of details, lest by so doing the broader issue may be lost sight of; suffice it to say that with scarce an exception the present mining laws of the Dominion, being wrong in principle, bristle with anomalies, ambiguities, and incongruities and the remedy is not in pruning but by striking at the root of them.

The consideration of the practical question alone remains, how is reform to be attained? What steps can be taken to bring about a better state of affairs? Certainly not by ordinary measures. Not by conventions, nor by committees. The Institute must bring all its influence to bear to awaken the Federal Government to interest and activity; and this activity could only be effectively expressed through the appointment of a Commissioner, whose duty it would be, after thorough investigation and enquiry, to enunciate the principles on which a sound and work-

able mining law should be based. This done, the framing of a model mining law for the Dominion would resolve itself into a question merely of fitting phraseology and arrangement. Finally the satisfactory operation of such a law would be so directly apparent as to bring conviction to the people and legislatures of the Provinces, and this secured, the road would be open for the accomplishment of that desideration, the Unification of the Mining Laws of Canada.

Discussion.

Mr. J. Obalski (Communication to the Secretary).—Minerals are vested in the Crown. It is, therefore, clearly the duty of those entrusted with the administration of the affairs of the country to dispose of these rights to the best possible advantage having regard to the general good of the community, but not neglecting to consider in particular the interests of the prospector, the mine operator and the investor.

Thus mineral rights, should be regarded as distinct from surface rights; and in the alienation of the former the mineral rights should invariably be reserved. On the other hand when disposing of the mineral rights to those ready to develop them, it is clearly the duty of the Government to ensure that every facility is afforded operators in the carrying out their undertakings. Consequently, in the framing of a mining law, provision should, of course, be made to enable the operator to acquire such of the surface as he may need for the proper conduct of his enterprise.

Again, in the framing of any mining law a basic principle to be observed is that protection and encouragement must be afforded the prospector; and further, it should be recognized that the discoverer of minerals is entitled to derive the full benefit of the fruits of his labour and enterprise, and has earned the first right to obtain possession thereof.

These, it is contended, are the two basic principles which should govern the framing of mining legislation designed to benefit the community.

An examination of the laws obtaining in older established communities discloses the fact that in the majority of cases the Crown or State, as the case may be, has retained its proprietary rights to minerals, the lands containing them, instead of being alienated, having been leased for stated periods contingent upon the fulfillment of certain well-defined conditions.

In new countries, like the United States or Canada, where the mining laws were, to all intents and purposes, drawn up by the miners themselves, the principle of the granting of freehold titles to mineral lands frequently obtains. But after a country has been settled for some time, the greater advantage of the lease-hold principle become apparent. Thus, in Ontario the proposal to impose an acreage tax on unworked mineral areas that would have the effect of compelling owners to either work their properties or abandon them to the Crown, is now favourably received. It is also proposed to introduce a system of royalties. The principle of the non-alieniation of mineral lands has long been in force in Nova Scotia, and the mining law in that Province has proved eminently workable. Until recently, however, the principle has not been in general favour elsewhere in Canada.

In the recent revision of the mining law of Quebec, an effort was made to conform as nearly as possible with the principles as defined in the opening paragraphs of these notes. The law had already created a distinction between surface and mining rights, and in disposing of land for agricultural purposes, a clause was inserted in the title reserving the minerals to the Crown. Again, when selling or leasing mining rights, the surface rights were reserved; but if the surface has already been parted with, provision is made whereby the miner or owner of the mining rights is able to acquire or expropriate from the owner such of the surface as he may require for the efficient and economical working of his property.

The principle of the right of the prospector to secure title to his discovery is also recognised in the law as amended, since he is permitted to stake out a claim of from forty to two hundred acres. If, however, this claim is in surveyed territory, it is stipulated that the area shall constitute a lot usually comprising one hundred acres. No discovery is insisted on, neither is recording, assessment work nor surveying of the claim required, the prospector being

merely obliged to notify the Bureau of Mines that he has staked out such and such an area, and the particulars are endorsed on his free miner's license. The posts set out by the prospector define his claim, and he is expected to protect his own interests by providing posts of sufficient dimensions, and by clearly defining the boundary by cutting out underbrush, etc., along their line.

With a view to discouraging the "blanketing" of areas, the Act contains a provision requiring a person applying for a claim to hold a miner's certificate, and to have himself staked out the property for which application is made. No fees or other payments are required by the Government for a period of four months after staking. But if at the expiration of this period, the prospector requires a regular title, he must take out a mining license, which gives him the right to work the property as a mine and to market the product. He is also required to pay a rental to the Government at the rate of one dollar per acre per annum. The interval of four months, however, during which the prospector is under no obligations, affords him the time and opportunity to prospect the property in order to ascertain its potential value, or to make arrangements either for the securing of capital for the development of the claim, or for its sale outright.

As an alternative, the prospector is given the opportunity of purchasing his claim. This, in unsurveyed territory, may be in forty acre blocks; but in surveyed territory, it is necessary to purchase lots of the areas of which are one hundred acres each. The purchase price is at the rate of twenty dollars per acre, if the property is within twenty miles in a straight line from an operating railway; or ten dollars per acre if the lot applied for is situated at a greater distance than twenty miles from such a railway. Before, however, the land is sold, it must have been surveyed, proof of discovery must be adduced, and a sum of not less than five hundred dollars in development operations must have been expended.

In conclusion, it is here affirmed that the present mining law of Quebec is clear and simple in its provisions. It is not, however, contended that critics will find it impossible to indicate objectionable features. Perfection, of course, is difficult of attainment, but if one journeys from a right starting point and there is no deviation by the way, one need never despair of reaching the goal at last.

DISCUSSION.

MR. A. C. VEATCH, Chairman Land Classification Board. United States Geological Survey (communicated to the Secretary), —I have read this paper with great interest.

I agree with the writer that the alienation of the fee in mineral lands is most unwise from a national standpoint and this viewpoint leads inevitably to an endorsement of the Australian system of Government leasehold. The matter of leasehold appeals to me not as a question of revenue but as the most effectual means of fully protecting the interests of both the public at large and that portion of it engaged in mining industry. The rapid settlement and development of a country will yield, indirectly, to the Government a vastly greater revenue than can be obtained through the imposition of heavy royalties in mining leases. The latter might for the time being yield a greater revenue; but it would be temporary only and would inevitably retard the growth of the nation.

The history of the development and practical workings of the mining laws of Australia contains many suggestions of interest and value at the present time both to the United States and Canada, for the reason that Australia has subjected to practical tests everything that has ever been tried in the United States, has rejected what was bad or unsuited to the location conditions and retained, modified and improved that which was good. Although the results may not be *in toto* applicable to the conditions in North America, the Australia mining laws contain many provisions which merit most careful consideration.

MR. J. LORN MCDOUGALL (communicated to the Secretary). —I do not greatly favour the idea of an uniform Mining Law for Canada, because nearly all mining laws have great practical weaknesses and it appears to me that it would be preferable that each Province should continue to experiment until a much more perfect law is evolved than any at present in force. On the strength of my experience in Cobalt, I believe conditions were more tolerable during the time when Government enforced the regulation in respect of "discovery." While I recognize what you say as to the truth of the contention that this regulation at times imposed hardships on individuals, on the whole it was in the interest of *bona-fide* holders. I do not agree that it served to promote "wild-catting," which in any case was inevitable. From our standpoint here "discovery" had the great effect of preventing the

tying-up of claims and was also some guarantee that when prospectors were engaged to go into the field, they would not stake worthless claims. Under present conditions the country has been blanketed for miles and claims are being held simply on the off-chance that they prove to be of value from the development of adjoining territory. It can be only a matter of a short time before there will cease to be any vacant ground in Ontario on which to prospect.

MR. H. MORTIMER-LAMB.—Mr. Lorn McDougall's contention is no doubt well founded; but he strays somewhat from the main issue. The insistence of the "discovery" condition is a mere adjunct of the Mines Act of Ontario. It was superfetated to discourage, or rather to discount a state of affairs made possible by the fundamental deficiency of the law itself. No one will dispute the value of antidotal treatment when emergency demands; but to quote a homely saying, "prevention is better than cure." In this case that is surely most true. Occasionally, too, antidotes themselves are not harmless in their effects upon the patient. The "Discovery clause" had its uses as well as abuses. One of the principal arguments in favour of leasehold as the basis of mining land tenure is that under such a system there would be no such thing as the "blanketing" of territory.

J. M. CLARK, K.C. (communicated to the Secretary).—I have read with keen interest the excellent and instructive paper by Mr. H. Mortimer-Lamb on the Deficiencies in Canadian Mining Laws.

The Canadian Mining Institute has for many years advocated the passing by the Dominion Parliament of a model mining law applicable to the mineral lands within its jurisdiction. This is needed for Dominion purposes; but there is the cogent argument in addition that the operation of such a mining law would have such far-reaching and beneficial results that the various Provinces would be bound to adopt similar improvements in the various Provincial Acts. There are, as justly pointed out difficulties and indeed serious obstacles; but these if firmly faced can speedily be overcome.

Education of public opinion is necessary and in this direction Mr. Lamb's admirable paper will perform a very useful function.

My opinion is that the fundamental principles involved are few, simple and well established.

THE NECESSITY OF DISTINGUISHING BETWEEN PROSPECTING, DEVELOPING AND MINING.

BY. R. W. BROCK, Ottawa, Ont.

(Annual Meeting, Toronto, 1910).

The rapid expansion of mining in Canada and the phenomenal successes attending operations in such camps as Cobalt have engendered in the public of Canada a real interest in this comparatively new Canadian industry. But since it is, to most Canadians, a new industry, there is the more need of vigilance on the part of technical men to preserve its reputability.

If the question were put to the members of this Institute, what is the most serious hindrance to the development of the mining industry of the country, they would, no doubt, unanimously reply "wild-catting." Money that should be invested in the development of the resources of the country, swells the profits of brazen and unscrupulous promoters; and the victims who would otherwise have become financial supporters of legitimate mining, pocket their losses, remarking that having bought their experience of mining, they will in future be careful to abstain from engaging in so risky a pursuit. The honest promoter, who will not make false statements or rash promises, finds it difficult or impossible to get money for his legitimate projects in competition with the glib fakir who is unhampered by considerations of conscience or fact. If "wild-catting" is such a millstone about the neck of the industry, it is fitting that the Institute, whose chief aim is to promote the welfare of mining, should take steps to eradicate the evil; and that men, more especially mining engineers, whose interests are so closely identified with the industry, should do everything possible to discourage this evil practice.

While the mischief of "wild-catting" is well recognized, it is not so easy to determine how to prevent it. The panacea is not to be found in protective legislation, although the laws might, perhaps, be made more effective. Possibly, however, the remedy lies in educating the public. This is a work that might well be undertaken by this Institute. The public must be instructed in that science, which may, for want of a better term, be called "mining embryology." At present, even in law, where fine, not to say hair-splitting, distinctions are supposedly drawn, any claim is termed a mine; any claim-holder, a mine-owner; any prospecting, mining. This looseness of definition and wrongful use of terms merely makes worse confounded the confusion in the mind of the layman.

If, then, the public were taught to draw sharp distinctions between the meaning of the words prospecting, developing and mining, an important step would have been taken toward rendering "wild-catting" ineffective. For the result of such teaching would be an early realization of the fact that of many thousand claims in a district, only a limited number rise to even the dignity of prospects, while of the prospects but a score or so will ultimately develop into mines. Having this knowledge the public then will be in a position to recognize as a "wild-cat" a claim or a prospect that is being offered or promoted upon the representation that it is a mine.

Some fear that if the uncertainties in connection with the business of mineral development are too freely indicated to the public, this course would have a tendency to discourage the investment of capital in such undertakings. But this point of view is quite untenable. Frankness in this respect would inevitably be beneficial in effect. It is true it might deter the small investor, who can ill afford to risk his savings, from engaging in mining ventures; but such a result could not be regrettably regarded.

Thus, were the public capable of forming a correct estimate of what may be referred to as the "relative probabilities" in mining, the distinction as between "actual mining operations," "development operations," and "prospecting operations" would become readily apparent. Mining investment would then rank with and be regarded as equally safe as investment in other industrial undertakings, and this would necessarily have a stimulating

rather than a depressing influence on investment included in the former class.

Again, neither development companies nor the promoters of legitimate undertakings of this character would experience greater difficulty in securing capital to carry out their projects; for the public would be quick to grasp the exceptional opportunities afforded by ventures of this description.

Large profits are the exception in mining. The price paid for a mine or for mining stock usually represents the full value of property, and provides only for a fair margin of profit in addition to the return of the original capital invested; for there can be no reason or occasion to offer for sale a property below its intrinsic value as so readily determined from available data in respect of the developed ore and the costs of extraction.

Hence, when fortunes are made in mining, it is usually by those who engage in "development" enterprises. Here, of course, one must be prepared to reckon with the element of chance; but this in itself is not a deterrent to enterprise. A man accepting a risk with his eyes open is, if unsuccessful, in a different position to one whose loss or failure is attributable to the misrepresentation of others, or to his own misconceptions.

Further, knowledge such as indicated will prevent the investor from paying for a prospect a price very far in excess of its value; it will impel him to require that such capital as may be subscribed towards the prosecution of an undertaking in which he embarks be devoted strictly to that purpose; he will, furthermore, require to be satisfied that any development company with which he associates himself is provided with adequate capital with which to acquire and test, if need be, of a number of prospects; and he will also insist that the best technical advice is secured in carrying on the investigation and operation in connection with the undertaking.

Under proper conditions, then, well organized and properly directed development companies would have every prospect of succeeding; and enterprises of this nature should afford a peculiarly promising and attractive outlet for the investment of capital in Canada.

The only individual likely to suffer by the education of the public is the unscrupulous promoter, whose welfare need not be a

matter of concern. If his means of livelihood be taken from him, so much the better. Industrial conditions would thereby be so much the more improved; for if but twenty-five per cent. of the money now misspent in the purchase of so-called mining stock were available under the conditions suggested, it is certain that the actual development and expansion of the industry would be greatly accentuated.

Mining engineers are not wholly concerned in money making. They are equally interested in the establishment, on a sound and worthy basis, of the industry with which they are associated. To educate the public to a more sensible and better understanding of the nature of the industry, to direct money, now wasted in foolish or fraudulent schemes, into needed channels for the development of the mineral resources, if not a duty, is, at any rate, in keeping with the ideals of the profession. It is, therefore, urged that mining engineers, both as individuals and as a body, engage in an endeavour whereby they may at once benefit themselves, stimulate the industry, and perform a much-needed public service.

DISCUSSION.

MR. TYRRELL:—The subject discussed in this paper is of vital interest to the mining industry; but there are one or two matters that may have been overlooked by the author. It is true that the rational development of the natural resources of the country affords a fair and proper scope for the investment of capital. People residing in localities where information is not readily available in respect of natural conditions, and especially of mineral conditions, may, therefore, be legitimately encouraged to invest part of their savings in the development of the mining industry. It is that feeling among right thinking men that gives the mining promoter the standing that he occupies; but the mass of those who invest small sums of money in mining are not usually in a position to secure trustworthy advice as to whether an investment is good or bad. Hence it is a legitimate function of Government to advise the public or to act for the public in such cases.

I heard some suggestions the other day that seemed to me to present the possibility of good results in this direction. For

instance, the Government might frame or amend the Joint Stock Companies Act so that in dealing with mining companies or promotions appealing to the public for money with which to develop mining claims, it would be made obligatory that a certain definite proportion of the money received from the sale of the stock in any mining development or prospecting enterprise, should be put into the ground. If the law provided that 75 per cent. of the money that might be collected from the sale of stock in a mining or development company should be actually invested in mining development, it might have a very salutory effect on the flotation of mining companies. It is only reasonable to allow the promoter a certain commission for the collection of the money; and, again, the Government could not possibly provide that such money would be wisely expended; but it could provide, I think, that a certain percentage of money received from the sale of stock of any mining company would be definitely invested in works of the company and actually spent in mining operations. If some such plan as that were provided for in the Companies Act, it should certainly prove beneficial

The promoter has always a strong inducement to take advantage of the credulity of the public which is ready to invest in any wild-cat enterprise, promising to produce large results from small investments; but I believe the Government would be perfectly justified in interfering to protect the small investor. (Applause)

A MEMBER:—I maintain that just as much harm is done by unscrupulous engineers as by unscrupulous promoters. The press, too, is continually condemning the practice of wild-catting; but my opinion is that the press is as much to blame as any institution in Canada in respect of the dissemination of unreliable information. But it should not be forgotten that there is considerable difficulty in defining what is a "wild-cat." Thus, in the Cobalt camp many enterprises have been started, that in the beginning were regarded askance, but that since have become profitable mines. We should also remember that there are honest as well as unscrupulous promoters, and the class as a whole should not be condemned. Honest promoting and honest engineering should go hand in hand for the common advancement of the industry.

DEVELOPMENT OF HINDERED SETTLING APPARATUS.*

By ROBERT H. RICHARDS, Boston.

(Annual Meeting, Toronto, 1910).

This is in part a review paper indicating the various steps that have been taken in developing hindered settling apparatus, some of the standard data that have been obtained, and some of the conclusions one is led to as to the effect of it in improving concentrating methods and machinery, and in part it brings in some unpublished work.

CAUSES OF LOSS.

In making a study of the separation of valuable minerals from the waste gangue, particularly by water concentrators, it is necessary to define, first of all, what are the causes of loss that are likely to interfere with the concentration. Having made this definition, we can then study to see in what way the machines make their losses and plan remedies for them in an intelligent way. Losses may be stated to occur as included grains, as flat or long grains, as fine free mineral, and as absolute slime. We will take these up one by one as follows:—

Included Grains.—Figure 1 shows by a set of diagrams how included grains may occur, first—where the heavy mineral grains attached to the quartz are of large size; secondly—where they are of small size; and thirdly—where very fine particles of heavy mineral are included in the quartz. We have to decide in regard

*This paper has also been read before the Western Society of Technical Chemists and Metallurgists, and the American Institute of Mining Engineers, and is printed by consent simultaneously in the Transactions of all three Societies.

to included grains whether they are rich enough to go direct to the furnace or poor enough to throw away, or whether they lie between these two points and require recrushing as the only means of severing the values from the waste. This last case is the only one requiring special treatment at our hands. We will therefore consider that next.

It will be noted that the valuable mineral is in coarse, medium or fine grains and that in order to sever these from the quartz so that the concentrator can save them we have to decide how fine the recrushing shall be. The exact size to which recrushing should be carried has to be determined in each case and may be stated to be that size which liberates the maximum of the valuable mineral while making the minimum of slime. Where valuable mineral severs easily from the gangue, if it is brought down to twice the size of the grains of the valuable mineral then they may be nearly all severed. If, however, the grains of valuable mineral do not sever easily from the gangue, then it may be necessary to break down to half their size in order to liberate a sufficient number of them completely from the gangue so that the concentrating machines can satisfactorily do their work. It follows from this that where the valuable mineral is in large grains coarse crushing is suitable, where it is in medium sized grains, crushing to medium sizes would be required, and where the grains are very fine, extremely fine crushing would be required.

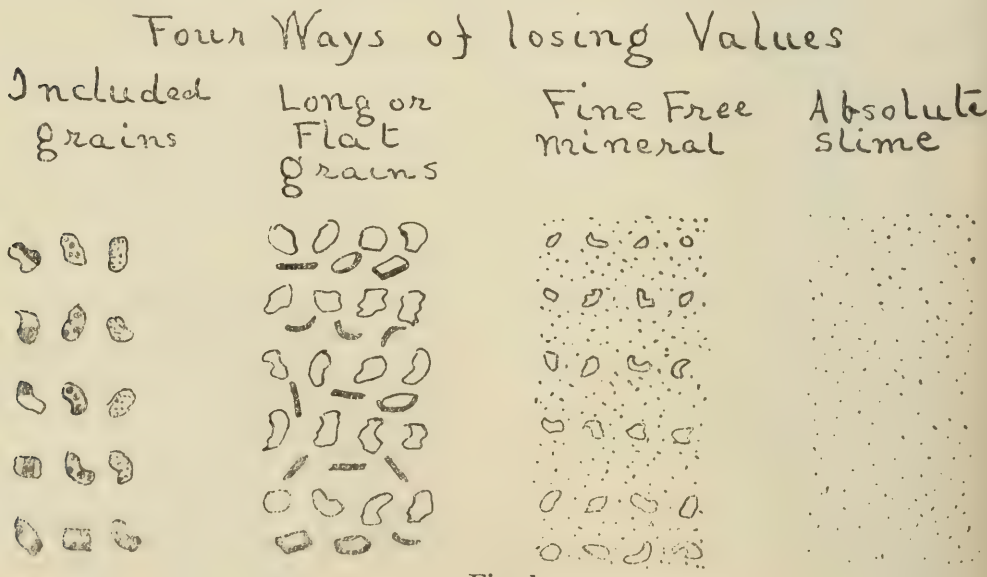


Fig. 1

FLAT GRAINS AND LONG GRAINS.

Of these two, flat grains seem to be much harder to save than the long grains, as the flat grains have such a large surface in comparison with their weight that they settle slowly in water and therefore are not placed where their gravity would seem to indicate that they should be. There seems no way of saving flat grains other than to recrush them and treat them just as if they were included grains. The size of recrushing here will have to be determined by the same consideration as was shown under included grains. Graphite being lighter than quartz is an exception to the above rule. Its flat form helps save it.

FINE FREE MINERAL.

(Fig. 1.)

Products containing fine free mineral are made by jigs and Wilfley tables which are fed with mixed feed, also when fed with the finest products of classifiers. They are also present in the tailings of vanners treating the ordinary stamp mill pulp and in the writer's opinion these three products, viz., jig tailings, Wilfley tailings, and vanner tailings, furnish the ripest field for improvement in milling. The object of this paper is to set forth the methods of saving this fine free mineral.

ABSOLUTE SLIME.

(Fig. 1.)

This is the title that has been given to us by Mr. David Cole, of Cananea Copper Company, and by it he means the grains of fine free mineral which are so fine that they cannot be settled in a reasonable commercial time. These grains cannot be handled, therefore, by settling. They can only to an imperfect degree be handled by the round table or by any of the film sizing machines, perhaps the canvas table is the most successful, and we may say that it is possible that some of the flotation processes may succeed in saving this class of grain. The matter in the author's belief is still unsettled as to whether they can be saved by any means or not. The Anaconda method of allowing them to go out in

a settling pond where the bulk of them settle in sufficient time to the bottom of the pond is one method of handling this product; but owing to the low per cent of values and the large quantity of gangue, it cannot be said to be a satisfactory solution of the problem.

TYPICAL FLOW SHEET.

(Fig. 2.)

Let us take up a general flow sheet containing the chief machines used in concentrating, placing them in logical order and briefly discuss the position of each.

The Grizzly and the breaker, let us assume, have brought the material to 25 mm. or 1 inch in size, and have fed it to the mill

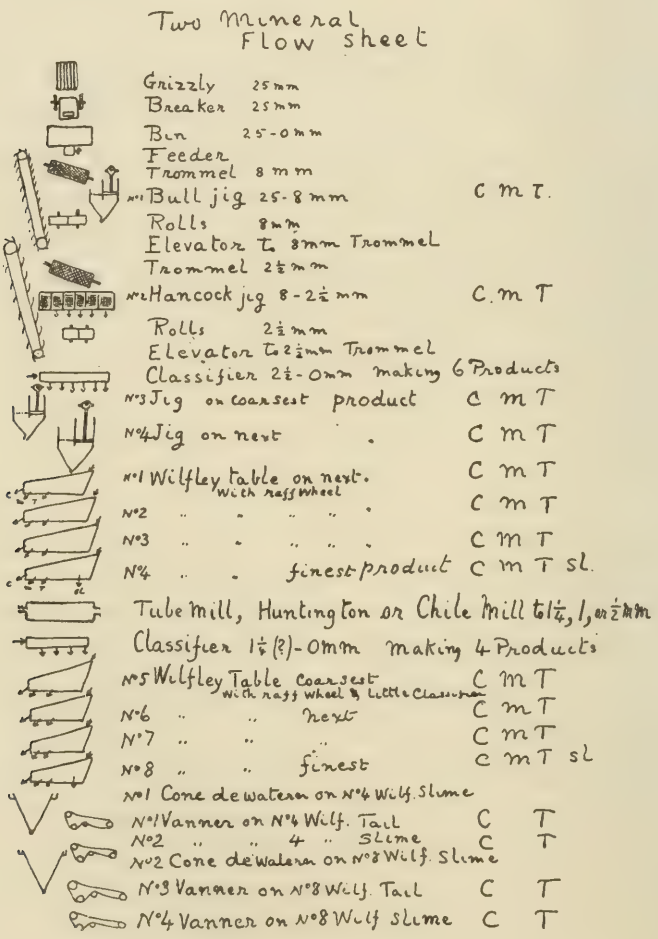

Two Mineral Flow sheet
Grizzly 25mm
Breaker 25mm
Bin 25-0mm
Feeder
Trommel 8mm
Bull jig 25-8mm C M T.
Rolls 8mm
Elevator to 8mm Trommel
Trommel 2½mm
Hancock jig 8-2½mm C M T
Rolls 2½mm
Elevator to 2½mm Trommel
Classifier 2½-0mm making 6 Products
N°3 Jig on coarsest product C M T
N°4 Jig on next C M T
N°1 Wilfley table on next. C M T
with rags wheel
N°2 C M T
N°3 C M T
N°4 finest product C M T sl.
Tube mill, Huntington or Chile Mill to 1¼, 1, or ½mm
Classifier 1¼(?)-0mm making 4 Products
N°5 Wilfley Table Coarsest C M T
with rags wheel & little Classifier
N°6 next C M T
N°7 C M T
N°8 finest C M T sl
N°1 Cone de Watera on N°4 Wilf. Slime
N°1 Vanner on N°4 Wilf. Tail C T
N°2 4 Slime C T
N°2 Cone de Watera on N°8 Wilf. Slime
N°3 Vanner on N°8 Wilf. Tail C T
N°4 Vanner on N°8 Wilf Slime C T

Fig. 2

bin. The feeder next sends it to a trommel with 8 mm. holes. The oversize of this trommel is fed to the bull jig which therefore treats 25 mm.--8 mm. material, yielding concentrates and middlings, or included grains requiring recrushing. The undersize of the trommel is fed to the next trommel with holes $2\frac{1}{2}$ mm. in size. The oversize of this goes to Hancock jig where it delivers concentrates, middlings for recrushing or to go back over the jig, and tailings either for waste or for recrushing, according to the richness and value of the ore. The undersize of this $2\frac{1}{2}$ mm. screen goes to a classifier and the two coarsest sizes go to jigs which yield concentrates and may yield tailings as waste and middlings for recrushing, or may yield only middlings for recrushing. The remaining four products from the classifier go to Wilfley tables and yield concentrates, middlings and tailings. Where Wilfley tables are fed with the products of a good classifier and are engaged in making a two mineral separation, the use of a raff wheel for returning the middlings to the table is not only a safe procedure, but wise, as the middlings form a very small product and one that is perfectly to be separated by the table. Any middlings made by the two jigs or by the coarsest Wilfley tables which contain a large share of included grains and therefore need re-crushing, may be broken by Chili mill, Huntington mill or Tube mill down to sizes $1\frac{1}{4}$ mm., or even to $\frac{1}{4}$mm. in diameter, according to the size that the included grains need to be broken. The pulp from this regrinding must go to another classifier where it is followed by Wilfley tables, and the final winding up at the fine end can be made by sending the tailings of the finest Wilfley tables of both classifiers to Callow screen, the oversize of which is clean gangue and the undersize makes a very perfect feed for the smooth belt vanner, and the slime from the finest Wilfley tables of both classifiers can be carried to a Callow cone and be finished up on vanners or other suitable machine. The tailings of these last vanners treating the fine slime will be the worst and, in fact, the only unsatisfactory product that will go out from such a mill. The writer will next take up the investigations that have been made and will refer to four investigations of the separation of sands by the free settling method.

FREE SETTLING TESTS.

(1) In "Close Sizing Before Jigging," (A.I.M.E., vol. xxiv, p. 409), using a tube 8 feet long and about 2 inches in diameter dropping about 50 grains together, free settling velocities were carefully determined. Tables 1 and 2 give for grains ranging from 1.84 mm. to .106 mm. diameter the ratios of diameters for grains of quartz and galena when they settle at the same rate.

TABLE I.

DIAMETERS CORRESPONDING TO VELOCITIES OF FALL; THE FASTEST GRAINS ONLY ARE USED FOR THIS.

		Velocity in mm. per second.								
		25.4	50.8	76.2	101.6	127.0	152.4	177.8	203.2	228.6
		Diameters of Millimeters.								
	Sp. Gr.									
Anthracite	1.473	.28	.686	1.244	2.030	.....	.....	.....	.....	.....
Quartz	2.64	.1399	.2415	.2795	.432	.762	1.041	1.346	1.650	1.905
Epidote	3.38	.089	.178	.2665	.381	.508	.648	.864	1.040	1.295
Blende	4.046	.....	.165	.2665	.368	.470	.635	.800	.978	1.220
Pyrrhotite	4.508	.....	.140	.216	.292	.381	.470	.597	.762	.914
Magentite	4.987	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chalcocite	5.334	.....	.127	.190	.268	.368	.457	.559	.665	.876
Arsenopyrite	5.627	.....	.127	.178	.228	.315	.406	.495	.571	.648
Cassiterite	6.261	.....	.114	.156	.216	.280	.355	.444	.533	.610
Antimony	6.706	.....	.089	.140	.216	.280	.355	.444	.546	.635
Wolframite	6.937	.....	.089	.152	.208	.267	.343	.419	.495	.585
Galena	7.586	.....	089	.152	.190	.254	.305	.368	.432	.507
Copper	8.479	.....	.089	.140	.183	.254	.325	.376	.432	.507

(2) In "Velocity of Quartz and Galena," (A.I.M.E., vol. xxxviii, p. 210), very complete figures of free settling velocities of quartz and galena are given ranging from 11.93 mm. diameter to .00152 mm. diameter, and these figures are the average of 100 observations each.

TABLE 2.

FREE-SETTLING FACTORS, OR MULTIPLIERS FOR OBTAINING THE DIAMETERS OF QUARTZ WHICH WILL BE EQUAL-SETTLING WITH THE MINERAL SPECIFIED WHEN SETTLING FREELY IN AMPLE WATER USING FASTEST GRAINS ONLY.

	Velocity in mm. per second.								
	25.4	50.8	76.2	101.6	127.0	152.4	177.8	203.2	228.6
	Multipliers								
Anthracite....	.500	.352	.225	.213	.....	.....	.....	.....	.....
Epidote.....	1.57	1.35	1.05	1.13	1.50	1.61	1.56	1.56	1.47
Sphalerite.....	.....	1.46	1.05	1.17	1.62	1.64	1.68	1.66	1.56
Pyrrhotite.....	.....	1.73	1.29	1.48	2.00	2.22	2.26	2.13	2.08
Chalcocite.....	.....	1.90	1.47	1.62	2.07	2.28	2.41	2.44	2.17
Arsenopyrite..	.....	1.90	1.57	1.89	2.42	2.56	2.72	2.84	2.94
Cassiterite....	.....	2.11	1.79	2.00	2.73	2.93	3.03	3.05	3.12
Antimony.....	.....	2.71	2.00	2.00	2.73	2.93	3.03	2.98	3.00
Wolframite....	.....	2.71	1.83	2.07	2.86	3.04	3.21	3.28	3.26
Galena.....	.....	2.71	1.83	2.26	3.00	3.42	3.65	3.76	3.75
Copper.....	.....	2.71	2.00	2.36	3.00	3.20	3.58	3.76	3.75

Example.—If a compact particle of galena, falling freely in water, settles 177.8 mm. per second, the particle of quartz of the same shape that will settle at the same rate will be approximately 3.65 times the diameter of the galena.

In these tests the largest grains were dropped one at a time 2800 mm. in a tube 8 inches in diameter, the intermediate grains were dropped 1000 mm. in a tube 2.87 inches diameter and the smallest grains were settled 500 mm. in a decanting tube, Bardwell's tube, 500 mm. high and 1.58 inches in diameter. While the ratios are somewhat different at the large end and also at the small end of the table, we find that the diameters of quartz grains from 2 mm. to 0.5 mm. are about 3.0 to 3.5 times the diameter of the galena grains that settle at the same rate under free settling conditions.

(3) In "Sorting Before Sizing" (A.I.M.E., vol. xxvii, p. 76), mixed quartz and galena grains were fed to a glass spitzlutte with sorting tube 24 inches high and $\frac{7}{8}$ inch diameter. The heavy grains of quartz and galena that were drawn off below were caught in the little bulb placed there to receive them, the lighter grains which could not settle rose and went into the overflow. By using a series of currents starting with the strongest rising 198.78 mm. a second and ending with the weakest, 1.26 mm., a second, the overflow of a stronger current each time was fed to the spitzlutte with the next weaker current. The series of bulb products so obtained from the series of rising currents form a very per-

fectly classified series of products, and present a very good opportunity for measuring with the microscope the average diameters of galena grains and of quartz grains found in each product (see Table 3). From these measured diameters we can again obtain the ratio of diameters under free settling conditions. The results of the work are given in Table 3, and we see that the ratio of diameters from 1.97 mm. diameter quartz to .589 mm. diameter quartz are again ranging from 3.70 to 2.92 or about 3.5 to 3. as previously found.

TABLE 3.

DIAMETERS OF QUARTZ AND GALENA PARTICLES WHICH ARE EQUAL SETTLING IN THE SPECIFIED UPWARD CURRENTS WHEN TREATED UNDER FREE-SETTLING CONDITIONS, TOGETHER WITH THE DIAMETER RATIOS.

Diameter of Particles in Millimeters		Particles Fall in Currents of Millimeters a Second	Particles Rise in Currents of Millimeters a Second.	Ratio. Diameter of Quartz divided by diameter of Galena averaged by curve.
Quartz	Galena			
.0301	.0194	0.00	1.26	1.54
.0335	.0198	1.26	2.51	1.68
.0568	.0292	2.51	5.05	1.82
.0772	.0412	5.05	7.42	1.96
.0982	.0488	7.42	10.01	2.09
.1423	.0613	10.01	14.68	2.23
.1875	.0721	14.68	19.80	2.35
.2254	.1032	19.80	30.12	2.48
.3416	.1305	30.12	40.37	2.61
.3880	.1404	40.37	50.08	2.72
.5241	.1708	50.08	60.09	2.82
.5892	.1997	60.09	70.34	2.92
.6590	.2381	70.34	80.28	3.03
.8604	.2750	80.28	90.21	3.12
1.0234	.3428	90.21	99.54	3.21
1.4224	.3504	99.54	110.09	3.29
1.3216	.3648	110.09	120.03	3.36
1.1424	.3776	120.03	130.43	3.42
1.4256	.4208	130.43	140.37	3.49
1.6032	.4560	140.37	150.31	3.54
1.6848	.4592	150.31	160.09	3.59
1.7488	.4624	160.09	169.95	3.63
1.8032	.5248	169.95	180.57	3.66
1.9746	.5776	180.57	180.50	3.70

(4) In "Free Settling and Hindered Settling Compared" (A.I.M.E., Feb., 1909, not yet in print), mixed quartz and galena grains were fed to an iron vortex spitzlutte, Fig. 3, working under free settling conditions. In each run of the series a weaker

rising current was used than in the run just before it, and in each run the spitzlutte was fed with the overflow product of the run just before it. In this way each run gave a heavy settling product. These settling products form a series ranging from large grains in the first to small grains in the last, and by sizing these products they can be laid out upon a board and photographed, see Fig. 4. This figure shows the little heaps of quartz and galena grains as obtained by free settling. This photograph is of special interest to us from two points of view:—

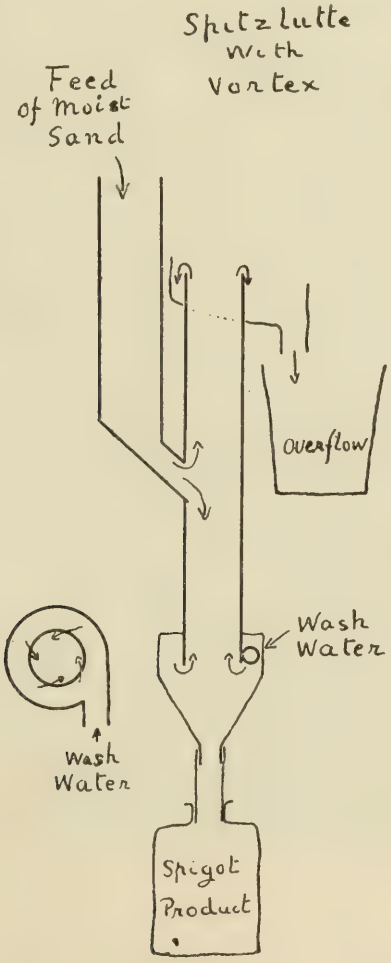


Fig. 3

(*a*) We may, for any and all products, for example, the product which settled against a rising current of 73.7 mm. a second, compute the average diameters of all the quartz grains and the average diameters of all the galena grains and if we divide the former by the latter we shall get the ratio of diameters,

3.71, of these quartz and galena grains which settle together under free settling conditions. If we calculate them for all the different velocities we get the figures in Table 4.

TABLE 4.

Beginning heaps—						
Velocities....	200.					
Ratios.....	3.208					
Middle heaps—						
Velocities....	144.	103.	73.7	52.8	37.9	27.2
Ratios.....	3.941	4.135	3.710	2.794	3.172	3.256
End heaps—						
						Rises in.
Velocities.			14.5	14.0	10.0	10.0
Ratios.....			1.802	3.216	2.844	1.334

The beginning heaps are too near the galena to be fair. The end heaps are too near the slime to be fair, the middle heaps represent the best we have for ratios. Here again we see the ratios from 3. to 3.5 more or less as the ratios for quartz and galena grains settling under free settling conditions, the average of the ratios of the middle heaps is 3.501.

(*b*) The second matter that is of especial interest to us is the relation of the two ranges of hills, note that the range of quartz hills is very close to the range of galena hills with only a very slight valley between the two. This is the characteristic result of separating grains by a free settling classifier. We have now reviewed four different methods of testing by free settling.

1st, by letting clusters of grains settle together; 2nd, by letting individual grains settle one at a time; 3rd, by spitzlutte and miscroscope to get the ratio; 4th, by spitzlutte and photograph to get the ratio, and we find that they all give results very nearly the same ratios of diameter for galena and quartz that are equal settling, namely about 3. to 3.5 for the range from $\frac{1}{2}$ mm. quartz to 2 mm. quartz.

FREE SETTLING MILL CLASSIFIERS.

I will now call attention to the virtues and faults of some of the practical classifiers.

To get the free settling method of classifying into a practical mill form, one must bear in mind that there are four things to be provided for:

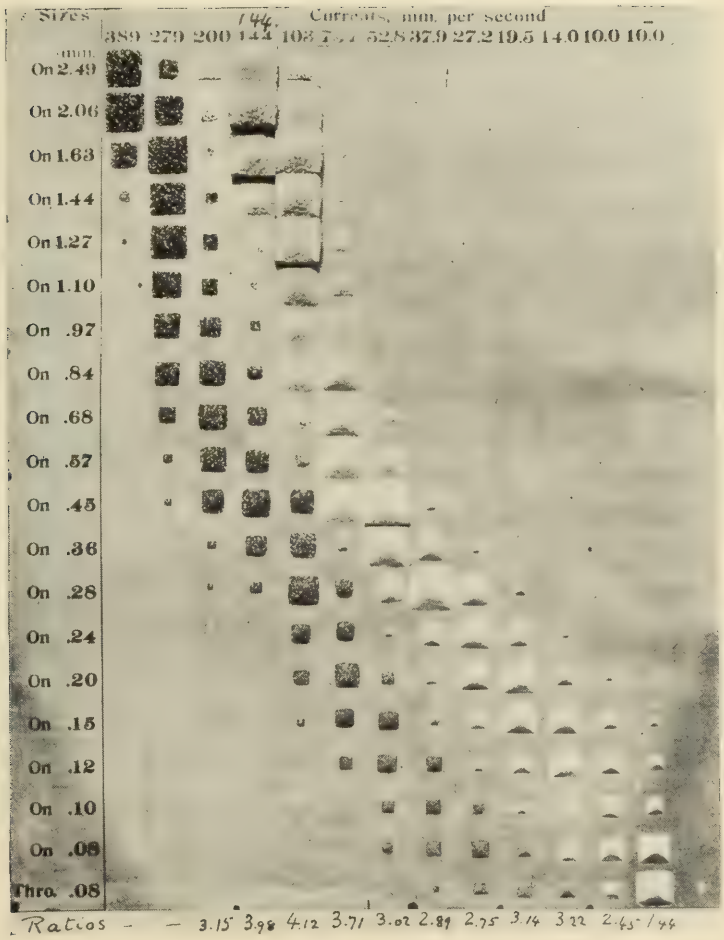

Sizes
144
Currents, mm. per second
389 279 200 144 108 52.8 37.9 27.2 19.5 14.0 10.0 10.0
mm.
On 2.49
On 2.06
On 1.63
On 1.44
On 1.27
On 1.10
On .97
On .84
On .68
On .57
On .45
On .36
On .28
On .24
On .20
On .15
On .12
On .10
On .08
Thro. .08
Ratios — — 3.15 3.98 4.12 3.71 3.02 2.89 2.75 3.14 3.22 2.45 / 44

Fig. 4

(*a*) We must feed the pocket or bring in the mixed sands to be treated.

(*b*) We must subject them to a rough sorting in the pocket, lifting out the finished light product or overflow, using the feed water with the rising water from the sorting column to do this work, and settling the heavy unfinished product to the sorting column.

(*c*) We must subject the above heavy product to a finishing sorting in the sorting column allowing the finished heavy product to settle down and out, while the entangled light grains are separated and lifted up to the pocket again. This sorting column must have the same velocity of rising current in all parts of a horizontal section across it.

(*d*) Finally, we have a pressure box into which the wash water is admitted and divides itself into two parts, that which rises and does the work in the sorting column and that which goes down and out the spigot with the discharged sand. This pressure box is a species of ticket office entrance gate through which the heavy grains are allowed to pass only after they are up to the standard and have obtained their ticket in the sorting column above.

The sorting column is the most difficult part of all the design, as it must not allow local down currents which would carry slime down into the spigot product, but it must have a steady even upward rising current to perfectly carry up and out all the lighter grains that do not belong in the spigot product. Classifiers are good or bad according as they do well or ill this one thing.

It may be further remarked that with all the pocket classifiers, the water in the pocket must have the same rising velocity as that in the sorting column in order that they may both lift the same size of grain. For all these matters of computation of classifiers the reader is referred to Ore Dressing, Volume III, p. 1375.

THE LAKE SUPERIOR HOG TROUGH CLASSIFIER.

The advantage of this classifier (see Fig. 5) is its simplicity. Nothing is likely to happen to it that will put it out of order. The disadvantage of it is that it does not keep slime out of the spigot products or prevent waste in fine free mineral in the Jig and Wilfley table tailings. The fault is due mainly to two causes. (1)

The sorting column is only the thickness of a board in height. and therefore, permits local down currents carrying down slime,

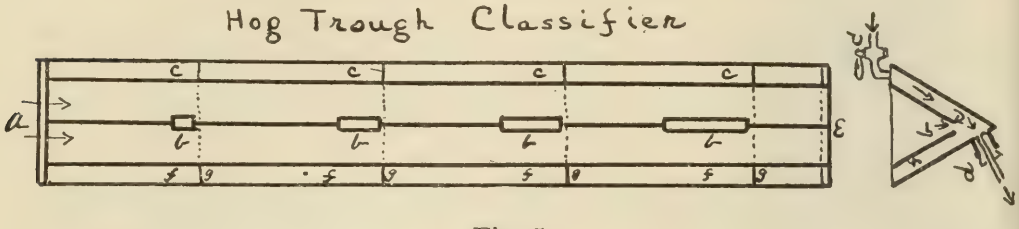


Fig. 5

(2) The rising current is not positive in its action, when the water is increased by the cock the full effect does not take place until the water has risen in the annular space between the inner and outer V to its full height, due to the increase. With this uncertainty, it is impossible to get good adjustments. Other harmful complications also arise.

THE CALUMET CLASSIFIER.

This has the "hydraulic" water flowing directly at and in line with the plug spigot (see Fig. 6) and the effect of adjustment of water is instantly felt. The slime is kept out of the spigots by the fact that the sand has to pass through an annular conical zone of clear water in order to get out of the spigot. The classifier is simple and easily kept in order and loses little mill head. This was the first positive classifier.

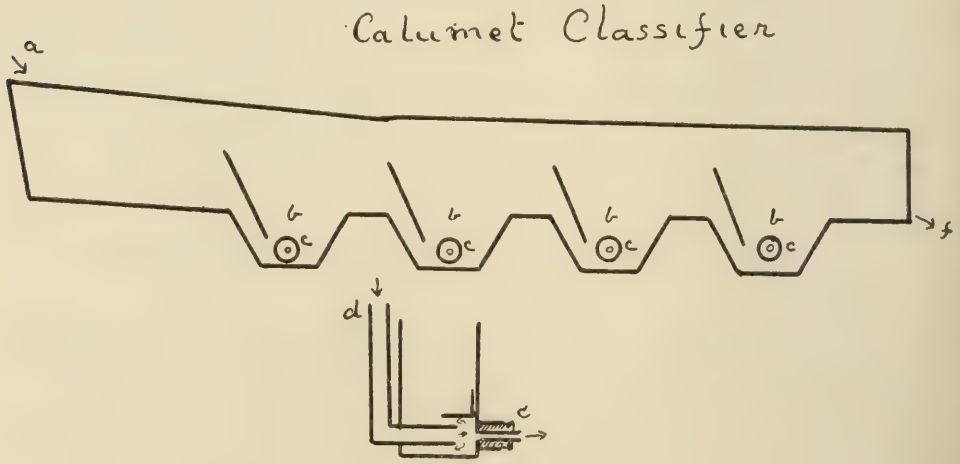


Fig. 6

THE EVANS CLASSIFIER.

This has the advantage of simplicity (see Fig. 7) and of being easily kept in order. It has, however, one rather serious disadvantage in the fact that it requires greater force in the rising current on the up stream side (*b*) of the regulating disc (*c*) than on the down stream side, this necessitates using more water on the down stream side than is necessary for cleaning the sand and makes the classifier a large water user.

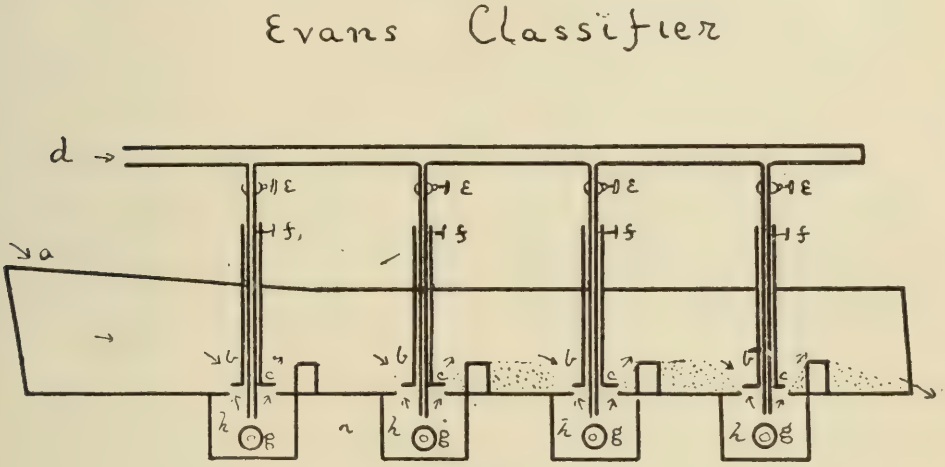


Fig. 7

WENGLER CLASSIFIER.

This consists of hopper shaped pockets (see Fig. 8) with feed and overflow of all on the same level. It has small vertical pipe

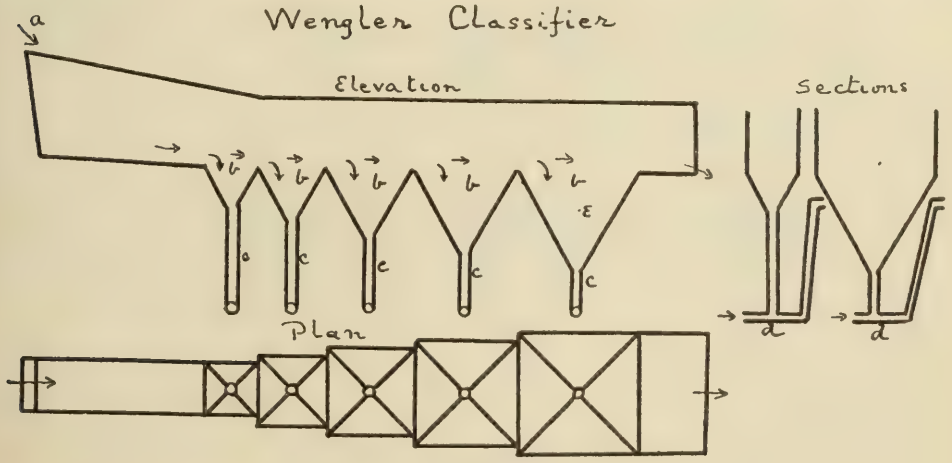


Fig. 8

sorting columns at the points of the hoppers. This was a very early design, made before the classifier was understood. It was as probably never put into use but once and then immediately thrown out. It has one fatal error, the hopper shaped pockets with small sorting columns below must necessarily fill up with hard sand banks, for the grains of sand that are just too small to settle in the rapid current of the small sorting column are much too large to be raised in the weak rising current in the large area at the top of the hopper pocket. The writer has put this in simply as a warning to the would-be designer.

LINKENBACH CLASSIFIER.

This is one of a number of designs (see Fig. 9) given by Linkenbach in his book, and shows a simple way of overcoming the trouble of the sand bank referred to under Wengler. The method is to have the overflow of any one pocket above the level of the feed of the next. This gives a plunging stream feed to all

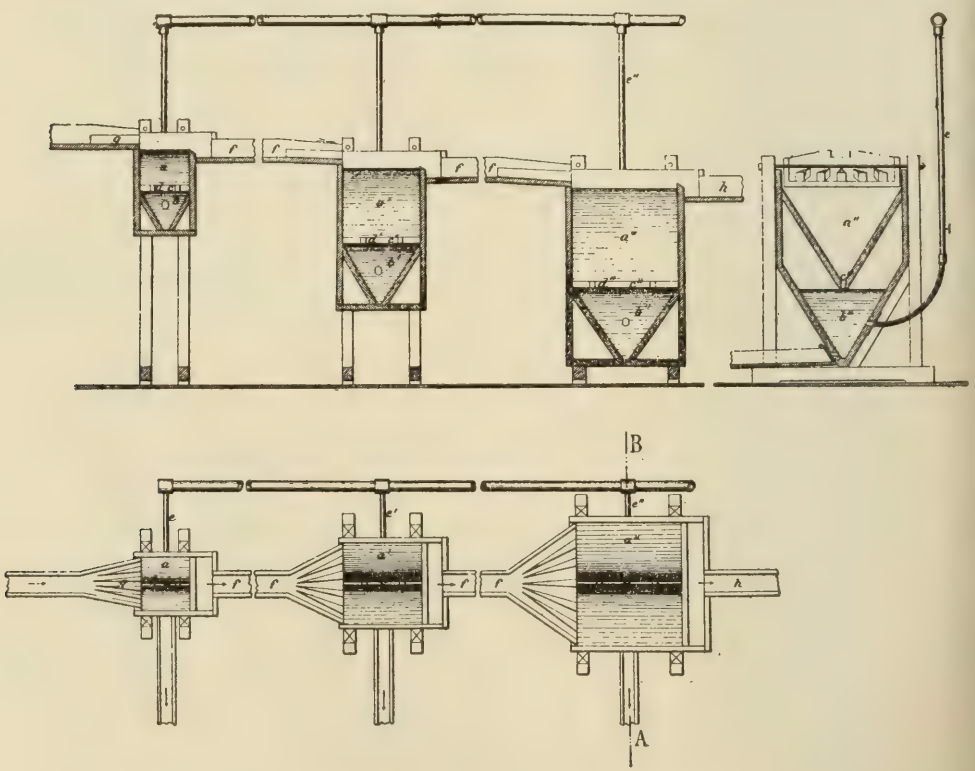


Fig. 9

the pockets and breaks up the sand banks carrying forward the sand to the next pocket. This method is not systematic and may carry forward larger grains into the later pockets than belong there.

POCKET VOTEX CLASSIFIER.

By having the pockets shallow and graded in size (see Fig. 10), so that an earlier smaller pocket settling large grains will have a stronger rising current, while a later larger pocket settling smaller grains will have a weaker rising current, the roughing work of the classifier of lifting out the most of the lighter grains is easily and perfectly done. The sorting column below is put on to complete the work of cleaning the spigot product. The hurtful down currents carrying slime into the spigot are prevented by admitting the "hydraulic" water in a vortex fitting. This gives a helical rising current that is a current flowing up in the direction of the thread of a screw. This classifier is simple and complete in its action.

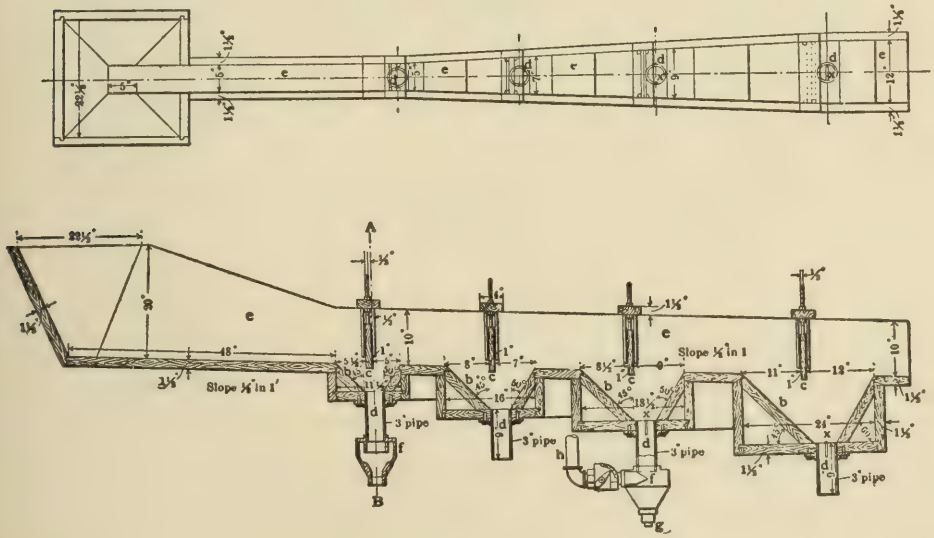


Fig. 10

THE TANK VORTEX CLASSIFIER.

This classifier (see Fig. 11) adds to the advantages of the pocket vortex classifier the fact that all the pockets are merged into one tank, and no careful grading of pockets has to be allowed

for. In case the design provides for a larger amount of feed water than is used, then the resulting tendency to form a bank is overcome by a safety spigot (*h*) in the end of the tank. This safety spigot product ranks as overflow and may be treated with the latter or as a separate product, as preferred. It will have slime mixed with its fine sand. This classifier is simple and complete in its action.

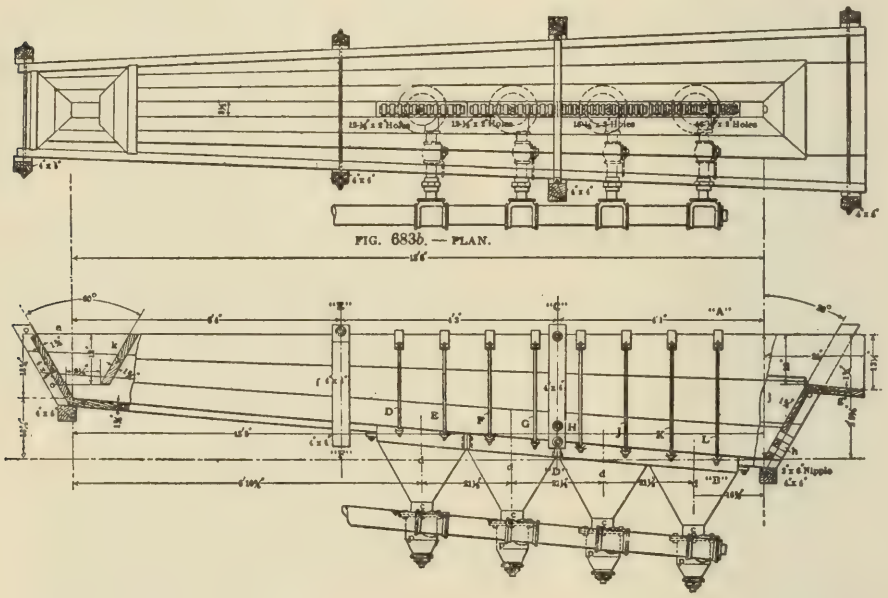


FIG. 6836. — PLAN.

Fig. 11

Tank Vortex Free Settling Classifier.

THE ANNULAR VORTEX COARSE CLASSIFIER.

This classifier (see Fig. 12) is generally used with one pocket only, and has found employment in two directions: (1) for cleaning the fine overflow of the log washer when used on brown iron ore where it saves 25 tons a day of good iron ore for the furnace; (2) for separating coarse sand for feeding the Hancock jig from the fine sand for the Wilfley tables. It makes use of the helical current of the vortex classifier for very much larger quantities than can be used in a simple pipe sorting column and does so without the danger of hurtful local down currents to carry slime into the spigot. In fact, it can be designed for almost any capacity.

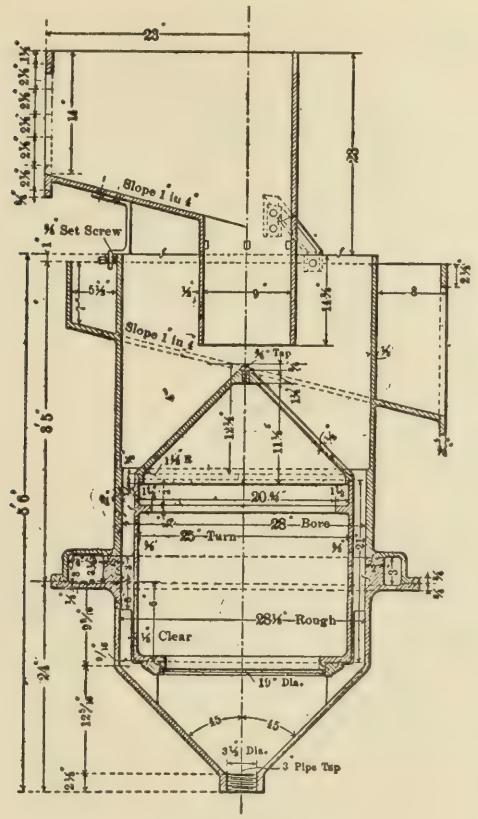


Fig. 12

THE ANNULAR VORTEX FINE CLASSIFIER.

This classifier (see Fig. 13) has an enlarged cone above the annular sorting column to enable the classifier to deliver a fine overflow product of any degree of fineness by the large diameter and consequent small velocity of the overflow. At the same time it delivers a spigot product free from slime.

THE CALLOW SLIME CONE AND WATER CONE.

These cones (see Fig. 14) are of two kinds: (1) the slime cone, which draws sand and some slime from the spigot and sends the slime into the overflow, and the water cone which draws sand and slime from the spigot and clear water, or nearly clear water, from the overflow. They have no rising hydraulic water. They are really settling tanks. The reason for mentioning them here

is to bring out the advantage they possess over the rectangular settling tank. An ordinary settling V tank, 6 feet wide, has an overflow 6 feet wide: an 8 foot water cone has an overflow 24 feet wide. If the two tanks have the same quantity (gallons a minute) to treat, the V tank will have four times the a mount of overflow per foot than the water cone has. The water approaching the overflow will have four times the velocity, and will therefore carry much larger grains into the overflow.

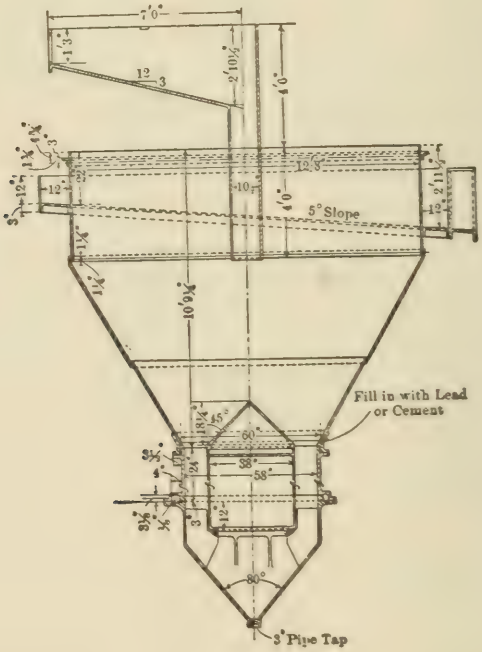


Fig. 13

The Work of a Free Settling Classifier (Fig. 15) is introduced to give more clearly the exact idea of what happens in a Free Settling Classifier. To the left of this figure will be seen a diagram representing a tall glass tube of water in which grains of sand can be allowed to settle and in which they will settle with velocities according to their size and gravity. The open circles at the left are supposed to represent quartz with a gravity 2.64, and they they show that the largest grain goes the fastest and the smaller grains diminish in velocity as their diameters diminish. Similarly the black circles represent galena with a gravity 7.5. Here the grains also settle according to their size, the larger going faster,

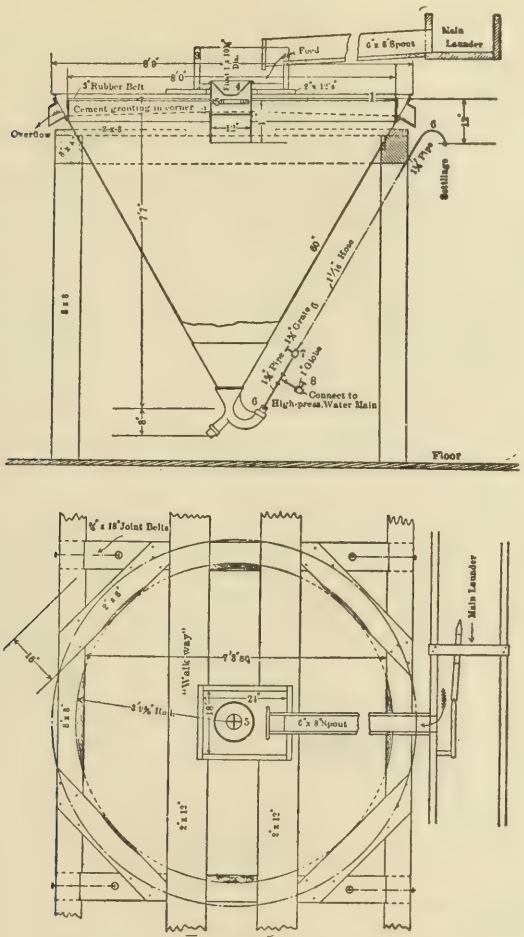


Fig. 14

but the galena grains settle much faster than quartz of same diameter. We at once notice that the grains are paired off, that there is in each pair a smaller grain of galena opposite the larger grain of quartz which is equal settling with it, and the quartz grains are, as we have already seen, about 3.5 times larger in diameter than the galena grains. These grains having the same velocity are said to be equal settling grains under free settling conditions, and they naturally belong in the same spigot of the classifier. If now, we suppose this complete group of grains to be laid in a horizontal position underneath the classifier, we shall see that each spigot receives its large grain of quartz and small grain of galena according to the equal settling velocities that have been discussed in the early part of the paper, that in succession the second spigot has smaller grains than the first, the third has

smaller grains than the second, and so on, diminishing until we we reach the final overflow, which contain the finest grains of all· but the most striking thing of all is the remarkable difference shown by the first spigot, for, besides the equal settling grains of the quartz and galena, we have all the added increment of larger grains of galena which find their way into this spigot in addition to the regular classified grains of quartz and galena, making the first spigot uniformly very much richer than any of the subsequent spigots. A supplementary condition occurs also

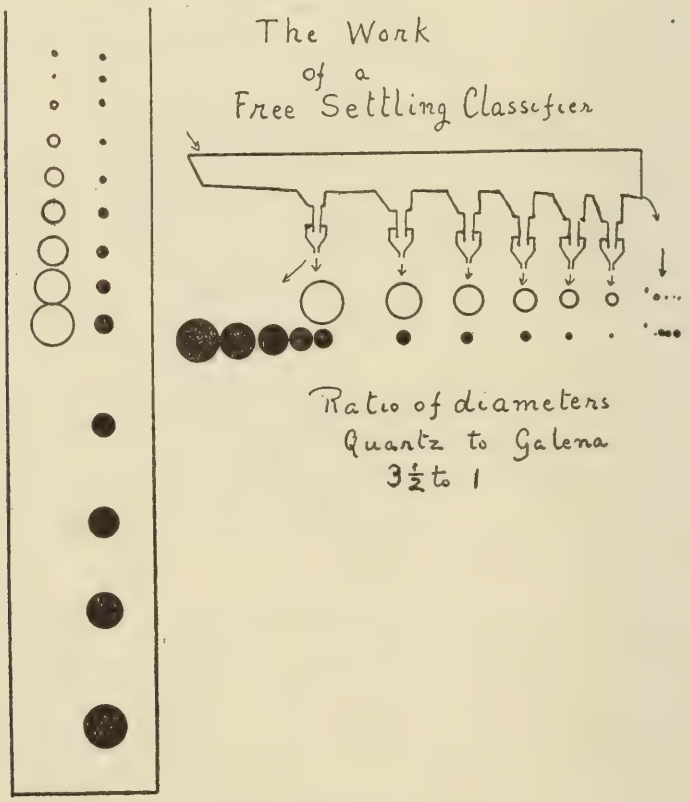


Fig. 15

in the overflow. Here the largest grain of quartz is much larger than the largest grain of galena, and this portion is the truly classified product, but in addition to this, the quartz ranges down to the finest dust, and the galena also making this product have an added increment of extra fine grains over and above the truly classified grains, making it differ from the truly classified products of all the intermediate spigots.

We see that all of the products of the classifier, except the that spigot and the last overflow, are truly classified products, that is to say, they contain larger grains of quartz and smaller grains of heavy mineral, but that the first has an added increment of a large quantity of coarse grains of the heavy mineral, which enrich it very largely, while the last overflow has an added increment of fine material over and above the truly classified grains. These facts, showing the difference between the coarsest and finest products, render it necessary to give these two products special consideration when they are being treated by concentrating machines.

HINDERED SETTLING TESTS.

Hindered Settling with Steady Current.—If in Figure 16 after turning the water on moderately by the valve *g* filling the glass tube and hopper to the overflow, we charge mixed quartz and

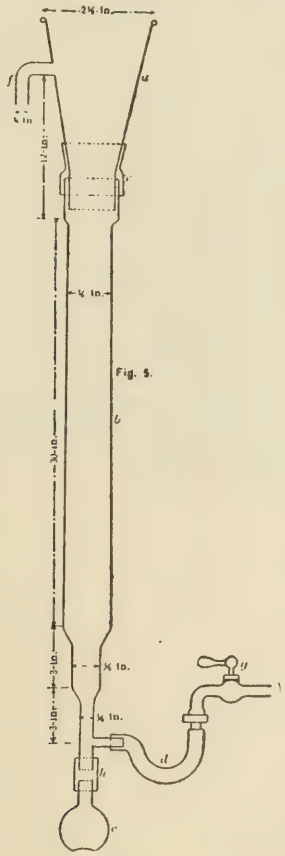


Fig. 16

galena grains from 2 mm. to 0 mm. (millimeters), in size and as the rising current of water is too strong to allow them to go through the $\frac{1}{4}$ inch tube constriction at the bottom, the grains will quickly arrange themselves according to their ability to settle under these conditions, fine grains at the top, coarse grains at the bottom, and it will be found that they are all in movement, teetering or oscillating up and down through short distances, like the grains of sand in a boiling spring. If one was to take out a grain from any part of the tube and drop it in at the top, it would settle down until it came to approximately the same position as that from which it was taken. These grains have arranged themselves according to the laws of hindered settling particles. If now we slacken the water and draw off a bulb full of sand, and we do it a second time with a new bulb, and a third time and so on, we get a series of products beautifully classified. We may now size these products on our series of sieves and lay them out on a board and photograph them, Fig. 17. After doing this we can compute for any bulb the average diameter of the quartz grains and the same for the galena grain and divide the former by the latter and get the diameter ratio for quartz and galena under hindered settling conditions, such a computation for bulbs 4, 5 and 6 gave the ratios in table 5:—

TABLE 5.

Number of Bulbs	4	5	6	Average.
Ratio of quartz to galena	6.325	5.656	5.544	5.84

showing a remarkable advance from the diameter ratio of free settling. See also the wide valley between the quartz and galena heaps. The same work has been done for the thirteen minerals referred to under free settling and the hindered settling diameter ratios given in Tables 5 and 12 obtained. See "Close Sizing Before Jigging" (A.I.M.E., vol. xxiv, p 409).

The writer was not satisfied with this first test as its field was too small and so had it repeated with a very long glass tube, 6 feet long, Fig. 18, which yielded 45 bulbs and from them after sizing, the photograph, Fig. 19, was obtained. Diameter ratios were computed from these bulbs and gave Table 6.

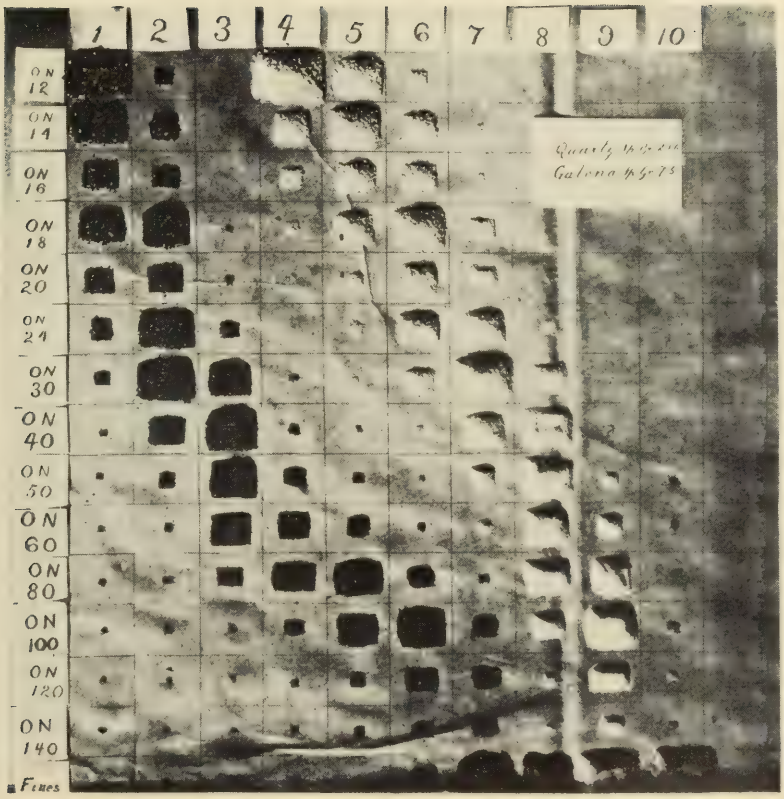

1
2
3
4
5
6
7
8
9
10
ON 12
ON 14
ON 16
ON 18
ON 20
ON 24
ON 30
ON 40
ON 50
ON 60
ON 80
ON 100
ON 120
ON 140
Fines

Fig. 17

TABLE 6.

Heavier products—										
Bulbs			12	13	14	15	16	17	18	
Ratios			4.6	5.19	5.68	5.72	6.03	6.11	6.07	
Intermediate products—										
Bulbs	19	20	21	22	23	24	25	26	27	28
Ratios	6.73	7.22	6.93	6.95	6.93	7.50	6.91	6.39	8.00	6.60
Bulbs	29	30	31	32	33	34				
Ratios	7.36	6.24	6.30	6.95	6.75	6.97				
Light products—										
Bulbs	35	36	37	38	39	40	41	42	43	44	45
Ratios	5.88	6.12	5.66	4.53	4.75	4.48	4.44	4.50	4.15	1.50	1.77

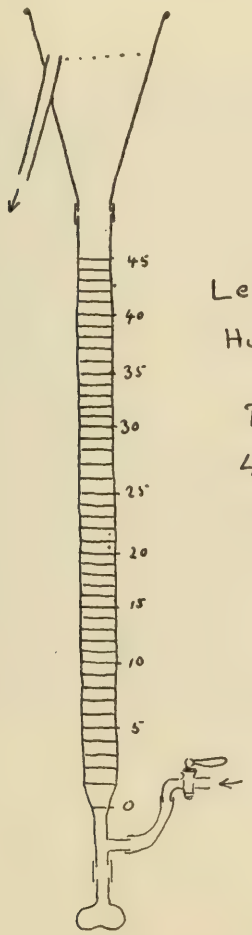


Fig. 18

Throwing out of the count the first few heavier products as being too near the galena to be fair, and also a few of the light products as being too near the slime to be fair, we get the above ratios from the intermediate products and their average is 6.92 showing a still greater advance over free settling diameter ratio than was shown in the first hindered settling test Observe, also

the wonderfully wide valley between the quartz and galena heaps in Fig. 8.

HINDERED SETTLING WITH PULSATING CURRENT.

With a view to see whether anything was gained by the use of intermittent pulsions in the place of steady current under hindered settling conditions, the following experiment was tried:— Figure 20 shows a hindered settling tube which has been cut apart

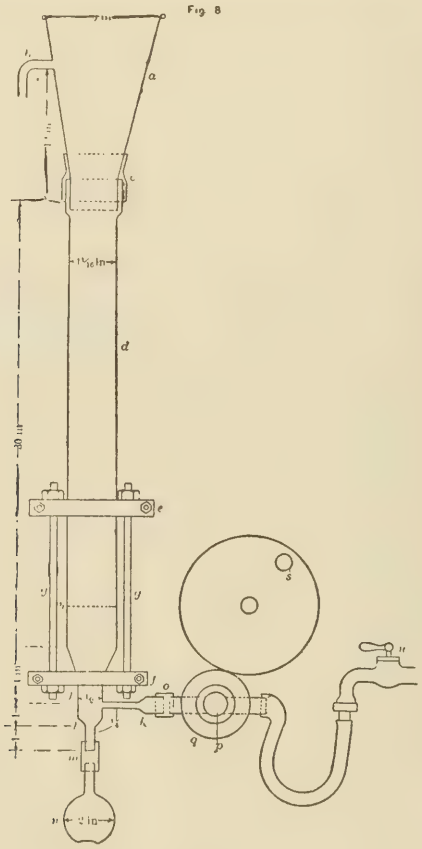


Fig. 20

and a sieve has been placed across it as a horizontal jigging sieve. Tests made with this tube indicated that the ratio of diameters was not advanced over that obtained by the steady current, and photograph, Figure 21, from this work is identical with photograph, Fig. 17, without pulsions. They, however, indicated that the pulsating current could be made to act much more evenly than the steady current, that is to say, the avoidance of down-

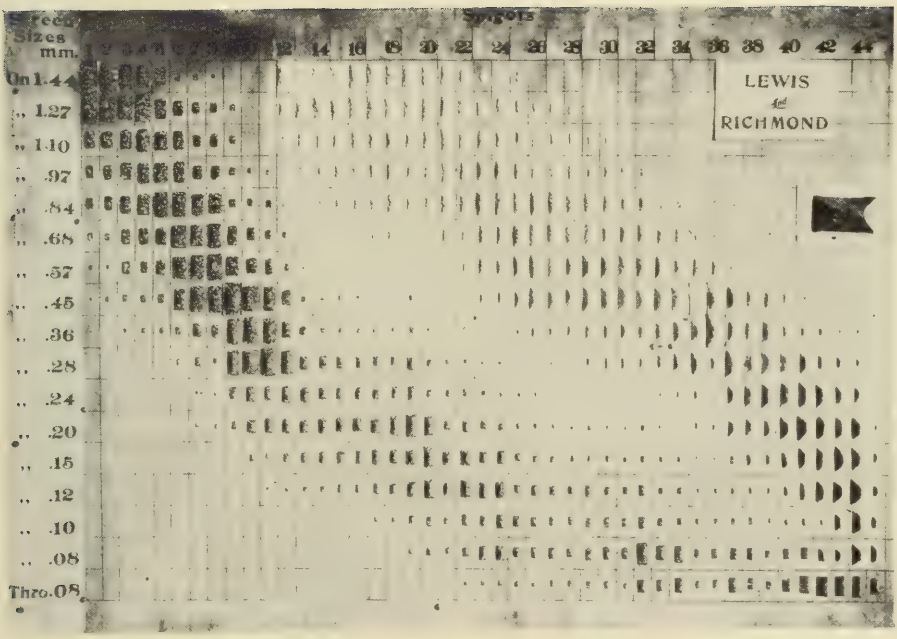

Screen Sizes mm.
Spigots
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
On 1.44
" 1.27
" 1.10
" .97
" .84
" .68
" .57
" .45
" .36
" .28
" .24
" .20
" .15
" .12
" .10
" .08
Thro. .08
LEWIS
and
RICHMOND

Fig. 19

ward hurtful currents could be gained to a much greater degree by the use of a pulsating current acting evenly all over the surface of the sieve than could be done with a steady current in both cases acting under hindered settling conditions.

Method of getting hindered settling.—It will be seen that the hindered settling apparatus has a constriction up through which the rising current comes whether by narrowing the tube or by the use of a sieve and that the tube widens out to a larger diameter and area in the hindered settling chamber above the constriction. This is the essential feature of the method of getting hindered settling, namely, a hindered settling chamber above and a constriction below it with the whole current rising up through the two.

Cause.—The cause of the difference between hindered settling and free settling appears to be that with free settling both the quartz and the galena are settling in water with a specific gravity of 1 and they obey the law laid down by Rittinger for particles settling in that liquid. With hindered settling, however, the grains are settling in liquid much denser than water with perhaps 1.5 specific gravity due to the crowding mineral grains. This when worked out mathematically should give a diameter ratio of 6.9 between quartz and galena and this is exactly what has been obtained in photograph, Fig. 19.

Effect.—The effect of hindered settling and the advanced diameter ratio is twofold. (*a*) The slime is more perfectly kept out of the spigot product than by any other method known to the writer, and (*b*) the advanced ratio really means that the hindered settling classifier has done more to help the concentrating machines which follow to do their work than has the free settling classifier. In proof of this, the reader is asked to compare the hindered settling photographs, Figs. 17, 19 and 21, with the free settling classifier photograph, Fig. 4. These photographs all represent the work of a classifier as a preliminary machine followed by screens as the finishing machine. Notice then how much farther the galena is removed from the quartz in the hindred settling photographs than in the free settling photograph. Notice, also, how much more galena is concentrated into the first spigot of the hindered settling than is in the free settling classifier.

REQUIREMENTS.

As the teeter chamber (hindered settling chamber) must have a constriction below it, it is necessary to know what should be the ratio of areas between the two. Clearly it cannot be so large a ratio as in Fig. 16 namely $\frac{1}{4}^2$ to $\frac{7}{8}^2$ =13, because when the current was strong enough to cause full teeter in the teeter chamber it was too strong in the constriction to allow any grain to go down and it cannot be a very small ratio as then it would simply be a free settling classifier. Clearly, there must be some ratio that is better than all others. The writer has worked long at this point and he thinks he now has end figures in sight. Up to-date he can say that a ratio of areas of 1 to 4 will work, that is, it will give a teeter chamber above and a discharge through the constriction at the same time.

THE JIG.

From what has already been said it will be understood that the act of *pulsion* or the moment of rising current in jigging is identical in its action with the hindered settling rising current. The plunger jig, however, adds another very important feature, namely, the act of *suction* or return downward current. This is caused by the rising of the plunger when returning preparatory to the next downward or *pulsion* stroke.

In "Close Sizing Before Jigging," read before the American Institute of Mining Engineers, February 1894, three series of tests were recorded which throw a great deal of light on this question. (1) A little glass hand jig, (Fig. 22) was used in such a way that the water at no time reached the top of the glass side *a a*. The lift pump-valve-action of the sand grains soon brought the water to its maximum height within the glass and then it was evident that the amount of water that arose through the sand during pulsion was equal to the amount of water that fell during suction, that is we had jigging with *strong suction.*

(2) The above glass jig was filled up with water until the water stood above the glass sides, *a a*, of the jig. When so adjusted a considerable portion of the water which arose during pulsion could overflow and therefore the amount of water which came down during suction was very much reduced. It was then jigging with *mild suction.*

(3) The glass pulsator jig, (see Fig. 20,) of this paper has pulsion only and therefore represented jigging with *no suction.*

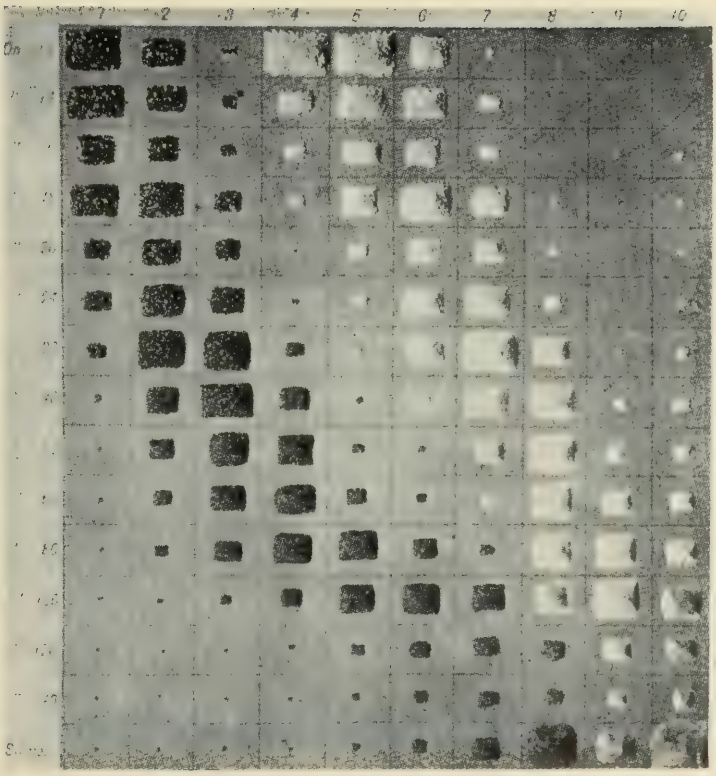


Fig. 21
Separation of Quartz (Sp. Gr. 2.64) and Galena (Sp. Gr. 7.586)
by Pulsator-Jig and Sieves.

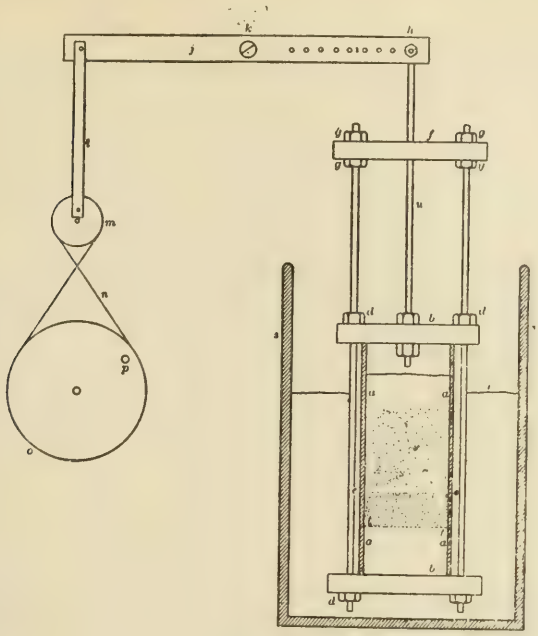


Fig. 22

Six tests were made in each series with each of the above three sets of conditions using the same size of quartz in all cases, but varying the size of blende from coarse to fine in each of the three sets.

The results are given in Table 7.

TABLE 7.

DIAMETERS OF THE GRAINS IN INCHES.

Diameter of quartz.	0.0683	0.0683	0.0683	0.0683	0.0683	0.0683
Diameter of blende.	0.0683	0.0429	0.0262	0.0195	0.0095	0.0042
SERIES 1 WITH STRONG SUCTION.						
Pulsions needed for separation.....	2129	1676	1757	297.	208.	288.
Percent. blende brought down...	96.	95.	95.	95.	99.	99.
SERIES 2 WITH MILD SUCTION.						
Pulsions needed for separation.....	306.	838.	846.	1382	1729	oo
Percent. blende brought down...	99.	99.	100.	98.	97.	0
SERIES 3 WITH NO SUCTION.						
Pulsions needed for separation.....	147.	202.	496.	oo	oo	oo
Percent. blende brought down...	98	95.	50	0	0	0

The results show that with a closely sized product .0683 inch quartz and .0683 blende strong suction is very slow (2129 pulsions needed) while no suction is extraordinarily rapid, 147 pulsions needed. On the other hand with 2nd spigot of a classifier where the diameter of the quartz is 3.5 times the diameter of the heavy mineral (.0195 x 3.5=.0683) much suction is very rapid, 297 pullions needed, while no suction would never make a separation (OO means infinity or never.) Mild suction appears to have been very satisfactory in either case.

The question, What is the cause of the great speed of the pulsator jig, will be taken up next under the title *Full Teeter.*

FULL TEETER.

When a water current rises, (see Fig. 23,) through a mass of sand where the grains are all of one size, if very slow it will not move the grains at all, if faster, the grains begin to move. By gradually increasing the current, we reach a speed where all the grains are moving so freely that they are immediately stratified according to gravity. When this speed is reached, we call the condition "just full teeter," that is, the weight of the grains is balanced by the rising water current and they are teetering up and down as a result like the grains of sand in a boiling spring.

The figures in these Tables 8, 9, 10 and 11, are the result of many trials, some of them as many as twenty trials, were made before adopting the figure.

TABLE 8.

HINDERED SETTLING FIGURES FOR GALENA SPECIFIC GRAVITY 7.5, AREA OF CROSS SECTION OF TUBE 4230 SQ. MILLIMETERS.

Size of Grain M.M.			Still Height Millimeter	Just full Teeter Height Millimeter	Just full Teeter, Hindered Settling Velocity. Millimeter Second if no sand	Free Settling Velocity Millimeter Second. x
Maximum	Minimum	Average				
7.66	5.58	6.77	108.	165.	212.4	697.7
5.58	4.06	4.97	112.	164.3	183.7	590.3
4.06	2.74	3.40	121.	167.7	141.9	505.1
2.74	1.95	2.35	119.	170.0	118.7	401.8
1.95	1.44	1.70	125.	165.7	90.42	350.2
1.44	.97	1.21	124.	175.0	77.18	272.8
.97	.68	.83	127.	177.2	51.84	213.1
.68	.45	.565	126.5	180.34	36.33	175.3
.45	.36	.405	126.5	186.18	15.40	124.8
.36	.24	.300	129.5	212.09	17.59	115.5
.24	.15	.195	136.4	219.20	10.32	77.08
.15	.00	.0705	151.3	.....	.....	28.44

x Very good figures from "settling velocity quartz and galena."

TABLE 9.

HINDERED SETTLING FIGURES FOR BLENDE SPECIFIC GRAVITY 4.00. AREA CROSS SECTION 4230 SQ. MILLIMETERS OF TUBE.

Size of Grain M.M.			Still Height Millimeter	Just full Teeter Height Millimeter	Just full Teeter, Hindered Settling Velocity. Millimeter Second, if no sand	Free Settling Velocity Millimeter Second y
Maximum	Minimum	Average				
5.58	4.06	4.97	115.0	165.7	125.9	.....
4 46	2.74	3.40	128.0	182.0	91.33	.....
2.74	1.95	2.35	128.0	187.0	70.65	.....
1.95	1.44	1.70	131.0	191 0	58.75	263.0
1.44	0.97	1.21	131.0	198.0	43.38	227.0
0. 7	0.68	0.83	134.0	208.0	35.15	181.0
0.68	0.45	0.565	138.0	216.0	24.59	143.0
0.05	0.36	0.405	140.0	238.0	16.82	109.0
0.36	0.24	0.30	143.0	256.0	10.96	86.0
0.24	0.15	0.195	147.0	275.0	6.70	59
0.15	0.00	0.075	157.0			

y From "Close Sizing Before Jigging." Not as good figures as those for quartz and galena.

TABLE 10.

HINDERED SETTLING FIGURES FOR QUARTZ, SPECIFIC GRAVITY, 2.64.
AREA CROSS SECTION 4230 SQ. MILLIMETERS.

Size of Grain M.M.			Still Height Millimeters	Just full Teeter, Height Millimeter	Just full Teeter, Hindered Settling Velocity. Millimeter Second, if no sand	Free Settling Velocity Millimeter Second
Maximum	Minimum	Average				
7.66	5.58	6.77	128.	200.	115.9	295.
5.58	4.06	4.97	129.	211.2	112.6	249.
4.06	2.74	3.40	128.27	171.0	68.72	207.
2.74	1.95	2.35	130.3	171.0	50.17	166.5
1.95	1.44	1.70	130.05	189.2	41.41	134.0
1.44	0.97	1.21	129.7	190.6	32.48	106.0
0.97	0.68	.83	133.35	202.4	20.79	80.5
0.68	0.45	.565	139.7	296.5	12.89	59.5
0.45	0.36	.405	140.97	.....	.....	41.5
0.36	0.24	.300	136.4	249.6	6.48	33.7
0.24	0.15	.195	148.6	277.6	3.31	23.0
0.15	0.00	.075	139.8	.....	.....	.....

TABLE 11

HINDERED SETTLING FIGURES FOR ANTHRACITE COAL, SPECIFIC GRAVITY 1.54 (memory figure).
AREA CROSS SECTION 4230 SQ. MILLIMETERS.

Size of Grain M.M.			Still Height Millimeter	Just full Teeter Height Millimeter	Just full Teeter, Hindered Settling Velocity. Millimeter Second, if no sand	Free Settling Velocity. Millimeter Second
Maximum	Minimum	meter Average				
11.01	7.66	9.34	122.	205.	104.6	No Figures at hand
7.66	5.58	6.62	124.	195.	71.63	
5.58	4.06	4.97	128.	195.	53.26	
4.06	2.74	3.40	128.	187.	41.37	
2.74	1.95	2.35	103.	193.	32.55	

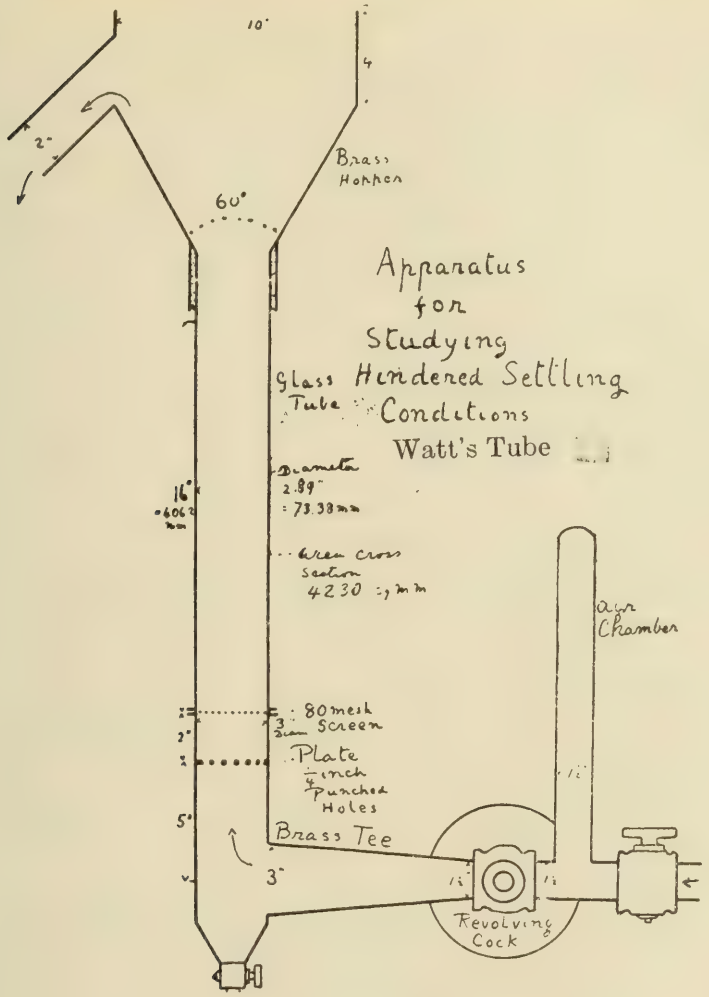


Fig. 23

Grains of quartz 3.4 mm. diameter, (see Table 9,) require for just full teeter a rising current 68.7 mm. a second (that is a quantity of water that would give this velocity if no sand was present) while these same grains under free settling conditions settle at the rate of 207 mm. a second. Galena grains 3.4 mm. diameter at just full teeter (see table 7,) require a rising current of 141.9 mm. a second, while the same grains settle under free settling conditions at the rate of 505 mm. a second. Let us see to what conclusion these interesting facts lead us. (See Fig. 24). If we are concentrating 3.4 mm. quartz and galena grains in pulsator jig, we must give the galena 141.9 mm. a second velocity of rising current in order that they may be at full teeter or liquid stratification. This 141.9 mm. a second is far above the just-full-teeter

velocity of quartz, in fact it is nearly up to the free settling velocity of quartz. We see then, that when galena is in hindered settling condition at just full teeter the quartz is so separated that the grains are far apart. We have in this phenomenon the answer to the question why is it that thepulsator jig can treat ore so much more rapidly than the plunger jig, for in the pulsator jig a grain of galena meets no resistance to settling through the quartz layer lying above the galena, while on the other hand, if we drop a grain of galena on the bed of a plunger jig and watch it, it takes five or ten pulsions before it settles into the quartz far enough to get out of sight. This clearly explains the remarkably high capacity of the pulsator jig.

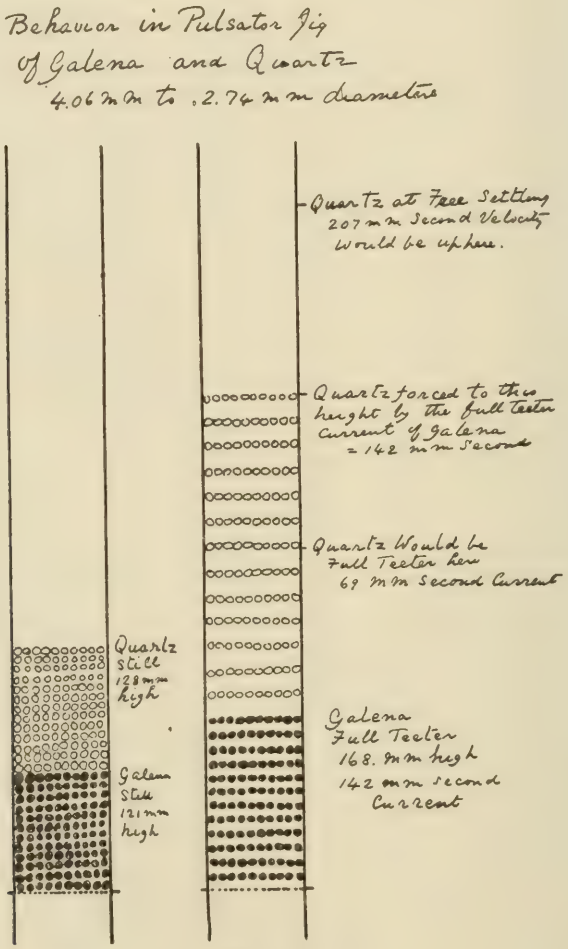


Fig. 24

Economy of water should be largely realized by the use of hindered settling. Since it requires only $\frac{1}{4}$ the velocity more or less of

that required by free settling to do the work, it should require only $\frac{1}{4}$ the quantity of water. As the designs are being improved this economy is more and more being realized. For example in the direct pulsator classifier, the quantity required is extraordinarily small, and in the pulsator jig, the water consumed is less than in the plunger jig. The No. 2 and No. 3 hindered settling classifiers have not yet been measured for water; but we believe they will economise water.

HINDERED SETTLING MILL CLASSIFIERS.

To get the hindered settling method into practical mill form, one must provide each compartment.

1.—Means of feeding with pulp (see *b* Fig. 25.)

2.—A teeter chamber or hindered settling chamber *h.*, in which the separation takes place.

3.—A constriction at the bottom *c.*, of the teeter chamber down through which the heavy product may or may not go according to the design.

4.—Means of removing the product by overflow discharge of spigot.

To put the hindered settling principle into practical final form the writer has made five designs.

The No. 1 Hindered Settling Vortex Classifier. Fig. 25.

The No. 2 Hindered Settling Vortex Classifier. Fig. 26.

The No. 3 Hindered Settling Vortex Classifier. Fig. 27.

The Inverted Pulsator Hindered Settling Classifier. Fig. 28.

The Direct Pulsator Hindered Settling Classifier. Fig. 29.

Taking these up in order, the *No. 1 Hindered Settling Classifier* (Fig. 25), shows at a glance its relation to the hindered settling test tube (see Fig. 5 and 7). Here one sees the hindered settling chamber *h*, and below it the constriction *c* for each of the pockets, and again below the constriction the pressure box furnishing the upward current in a helical form and also the water for the spigot. This classifier submits the sand to hindered settling treatment in the hindered settling chamber, the grains there being in the condition of teeter, the heavy grains quickly going down and out

and the medium grains remaining at full teeter act as a filter for filtering out the fine slime. Fine free mineral is scarcely discernible in the tailings of Wilfley tables treating these products.

No 1 Hindered Settling Classifier

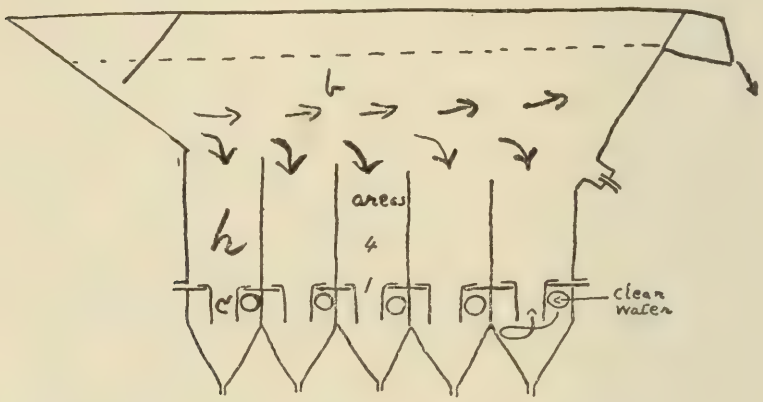


Fig. 25

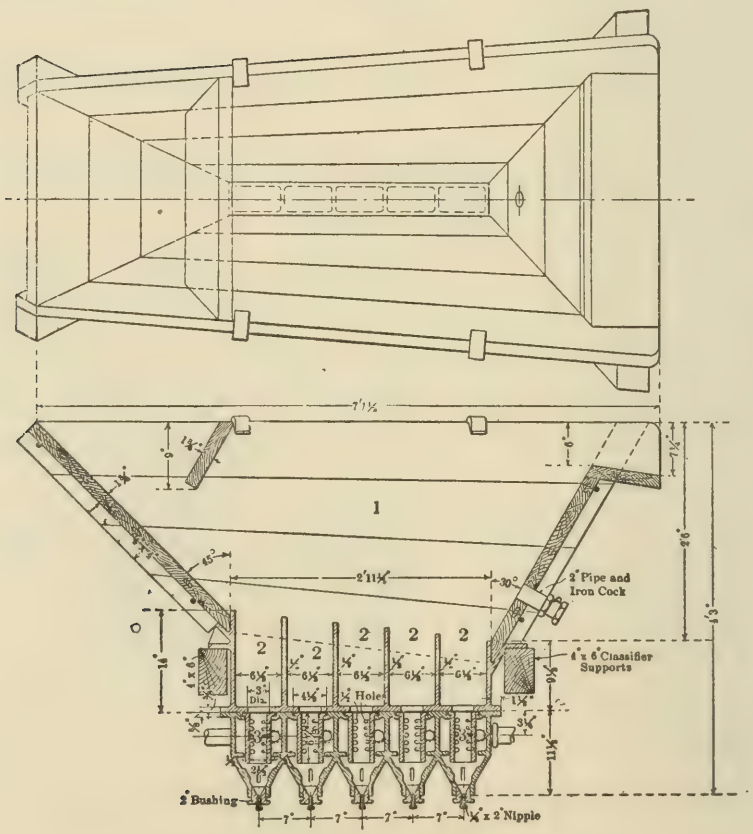


Fig. 26

The No. 2 Hindered Settling Classifier (see Fig. 26), has constriction considerably longer than in the No. 1, and it has the additional feature of a lot of little vortex jets (20 in all) for giving it whirling current to the water in the constriction. This makes a still more impossible for the constriction to have a downward current on one side with upward current on the other, carrying slimes into the earlier spigots, and thereby guaranteeing tailings free from fine free mineral.

No. 3 Hindered Settling Classifier (see Fig. 27), instead of a hindered settling chamber above, and a constriction below with vortex jets in it as in No. 2, has these two parts merged into one in conical form with inflowing jets all the way from the top to the bottom. The inflowing jets however have three variations which should be mentioned. They are in layers alternately radial jets and vortex jets, the vortex or tangential jets breaking up a possible sand bank in the form of a shell around the margin, and the radial jets breaking up a possible core bank of sand in the centre. Further, the upper holes are smaller in size, $\frac{1}{4}$ inch diameter, more or less, and only 4 to the circle or layer, whereas the lower holes are larger in size, $\frac{1}{2}$ inch more or less in diameter, and 6 of them to the circle or layer. The conical form combined with the arrangement of jets just referred to, gives maximum rising current two thirds of the height down, and gives a steadily diminishing velocity of rising current as the water rises in the cone. This guarantees a hindered settling chamber in upper part of the cone. This arrangement lowers the neutral plane which lies between the rising current which does the sorting, and lifts out the light stuff, and the descending current which carries down the heavy grains to be discharged out at the spigot. By putting this plane considerably lower, it is believed that this No. 3 Classifier is more perfect than the No. 2 from the theoretical point of each, and by having layers of jets made alternately radial and tangential, it is believed that the elimination of possible harmful currents is thoroughly accomplished, and that tailings made from treating these products will be free from fine free mineral.

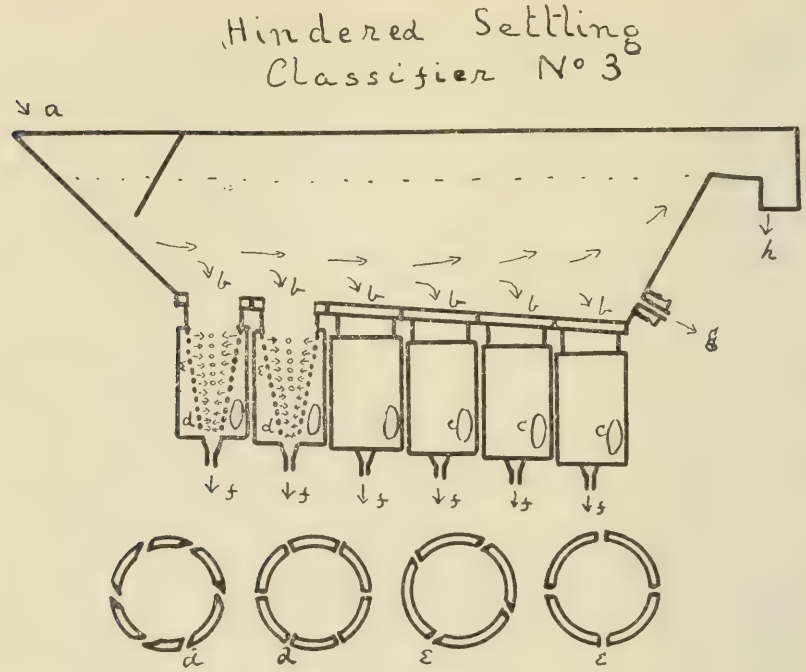


Fig. 27

The Inverted Pulsator Classifier (see Fig. 28), is another mode of doing away with the hurtful downward currents. It is believed that oft repeated pulsations will give an extremely even rising current when passing up through a mass of sand, first—because it comes by pulses, and second—because it comes through the sieve at high velocity compared with full teeter if the meshes of the sieve are 25 the per cent of the area, then the velocity when passing the sieve is four times that in the space above. The coming water attacks all parts alike through the meshes of the sieve which act as the constriction. This classifier (see Fig. 28), has been designed to make use of this principle. It will be seen from the figure that the feed water and sand enter the apparatus in the feed hopper, that the feed hopper has a pulsating bottom to prevent the sand from solidifying and forming an obstruction on the bottom. This pulsation is given by the pulsating rising current up through the sieve in this compartment as in all the succeeding compartments. The liquified sand then passes into the first compartment, and the pulsating rising current lifts out all of the lightest grains of slime and sand as overflow, the first two products carry all the slime and give the densest slime of any classifier known to the writer. All the heavier material finds its way forward by passing under the

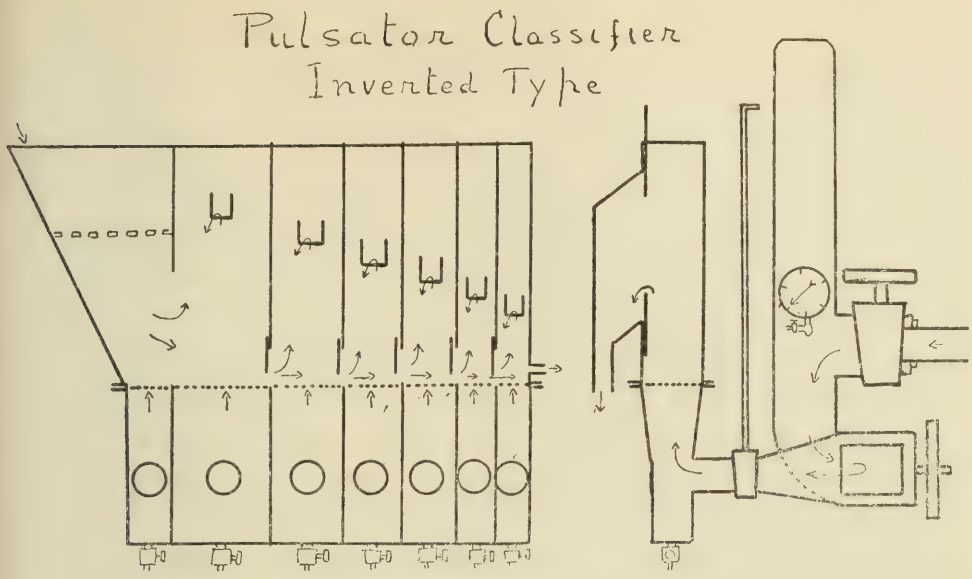


Fig. 28

partition gate into the second compartment receiving its force to do so by the diminished height of overflow, and therefore, head of water in the second compartment as compared with the first. The second compartment again repeats the act of the first in lifting out the lighter parts by the rising pulsating current and allowing the heavy parts to flow into the third by the diminished head of the third as compared with the second, and so on, to the fourth, fifth and sixth compartments. A safety spigot in the end, just above the sieve of the sixth compartment, may be used in case an excessively heavy bank forms in that compartment. This gives a seventh product. Each compartment of the series discharges a heavier product than the one before it and each furnishes a very perfect classified product. The slimes that come in with the feed are taken out by the first and second compartments and appear in those two products. The Wilfley tables which treat these two slimy products cannot make tailings free from fine free mineral with one treatment as all the other Wilfleys can. They require an additional treatment. The tailings of the Wilfley table treating the 3rd and 4th, 5th and 6th spigots of this classifier are as clean and free from fine free mineral as it is likely will ever be obtained in mill practice. One may say that they are commercially free from free mineral. The 5th and 6th products may yield tailings on jig or Wilfley table with sufficient amount of included grains to make their further treatment by re-crushing and retreatment necessary. The latest form of revolving cock for getting the pulsating current

is designed with the feed water entering the end of the hollow cylindrical revolving part and discharging through two ports on opposite sides. This makes it a perfectly balanced valve and prevents the valve from pressing too hard on the valve seat. This alternate opening and closing of a revolving cock gives an alternating condition of rising current and repose repeated perhaps at the rate of 200 times a minute and produces the desired result. By using a single revolving cock and distributing the current through seven regulating cocks, the seven compartments can be furnished each with its own pulsating rising current. The air chamber used with this apparatus differs from the air chambrse ordinarily used with pumps and other hydraulic apparatus in that the latter are used simply to diminish the shock due to the water hammer while this air chamber is used mainly for the purpose of giving sudden impulse to the water the instant the revolving cock is open. This impulse is due to the elasticity of the air and without it the classifier could not be operated. The avoidance of shock is necessary with the classifier as it is with all hydraulic apparatus; but it is not the main feature for which the air chamber is used. For the method of cleaning up the first and second products of this classifier, see the description of the treatment of the slimes of the direct pulsator classifier. The method in both cases is the same.

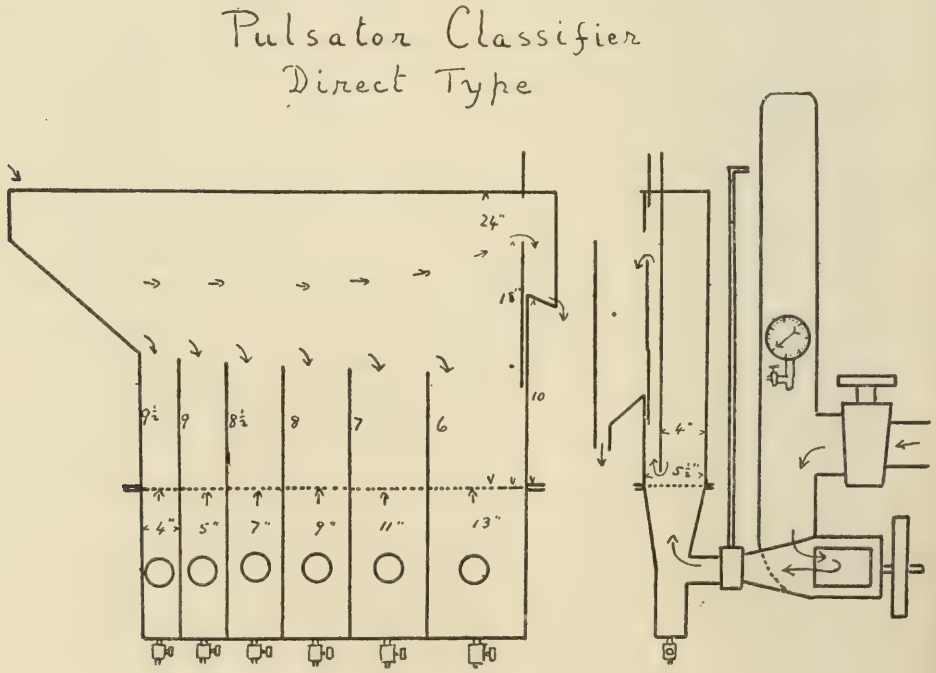


Fig. 29

The Direct Pulsator Classifier differs from the Inverted (see Fig. 29,) in the fact that the pockets do not have connections with each other at the bottom of the dividing partitions, and in consequence the earlier pockets overflow into the later within the machine instead of overflowing as separate products. All the compartments receive pulsating rising current and as a result the first compartment gives the heaviest largest grains and the final overflow gives the lightest. The several compartments discharge their products either by the gate and dam discharge, commonly called the cup discharge, used in jigs or by the ordinary plug spigot. The latter is the simplest and is very good. It yields its series of products graded from coarse to fine. It is not difficult with this classifier to bring the discharge of the first compartment up to a quality of finished concentrates and in this way eliminate one jig from the set of finishing machines. If the first be made a finished product the second can go to the Harz jig and it will be found to give tailings free from fine free mineral. These tailings are free from fine free mineral but they may have included grains and require recrushing and retreating in consequence. The succeeding spigots, 3rd, 4th, 5th and 6th, can all give tailings free from fine free mineral when treated on Wilfley tables. This fulfils the requirements of milling, leaving only the slime as the single product to be finished, and this can be finished by running it upon the Wilfley table making tailings containing fine free mineral which are finished by Callow screen sending undersize to a vanner. The oversize of the Callow screen and the tailings of the vanner will both be free from fine free mineral. The slime from the Wilfley table will have to be treated by vanners or by any of the slime methods best approved in the district under consideration.

The Pulsator Pebble Sand Slime Cone. for separating sand from slime, (see Fig. 30.) This cone has been tried on a small scale and has shown remarkable abilities for separating sand and slime. By using pebbles perhaps one inch in size supported on a very coarse screen, a pulsating current furnishes a very perfect separation of sand from slime. When one realizes that the rising current in the interstices is about four times what is in the space above, one sees that there is great opportunity for regulation of the rising current and for the avoidance of downward currents carrying slime into the sand.

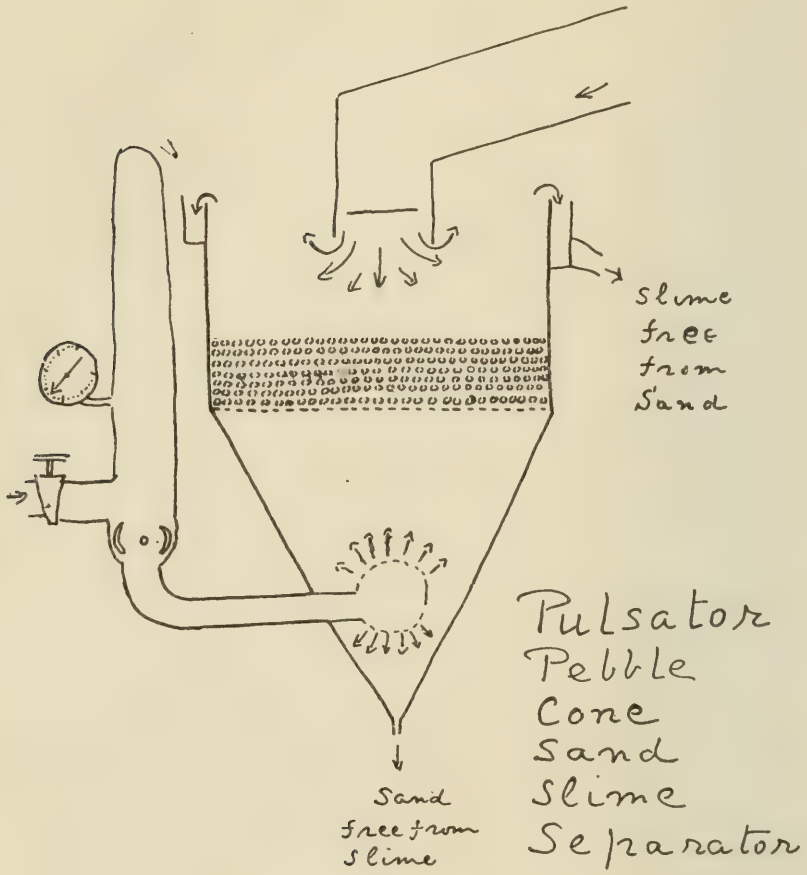


Fig. 30

THE WORK OF THE HINDERED SETTLING CLASSIFIER.

Figure 31 represents the work of a hindered settling classifier. The side tube represents here the relations between the grains of quartz and galena under hindered settling condition, namely, the quartz grains in juxtaposition with the galena grains are 6.9 times the diameter of the latter. Laying this diagram down under the direct pulsator classifier we have an illustration of the products made by a hindered settling classifier. Just as the free settling classifier had an added increment of heavy mineral in the coarsest spigot, truly classified products in all the between spigots and an added increment in the finest product of slimes, so has this hindered settling classifier. It however differs from the free settling classifier in having a very much larger ratio between the diameters of the grains in juxtaposition in the between

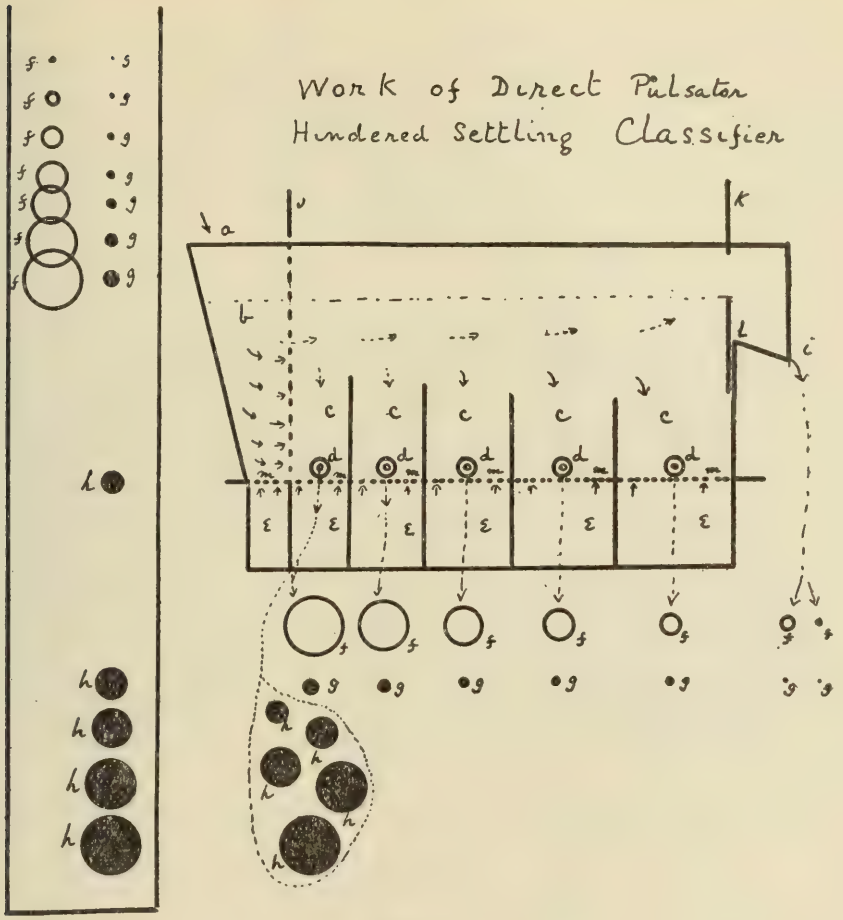


Fig. 31

products, namely, the quartz grains are 6.9 times the diameter of the galena grains associated with them and as a consequence the coarsest product has a much larger proportion of all the values in it, than was the case in the free settling classifier. The amount of water in the spigots and in the overflow is much reduced from that in the free settling classifier. The fine free mineral grains liable to contaminate the tailings of the concentrators that follow are much easier kept out from those tailings. What I have said here of the direct pulsator classifier is in the main true of hindered settling classifiers No. 2 and No. 3 and also of the Inverted pulsator classifier. The latter does not reduce the water in the spigots so much but reduces the water in the overflow more.

Mill Concentration.—Some of their faults and the benefits they derive from sizing or classification.

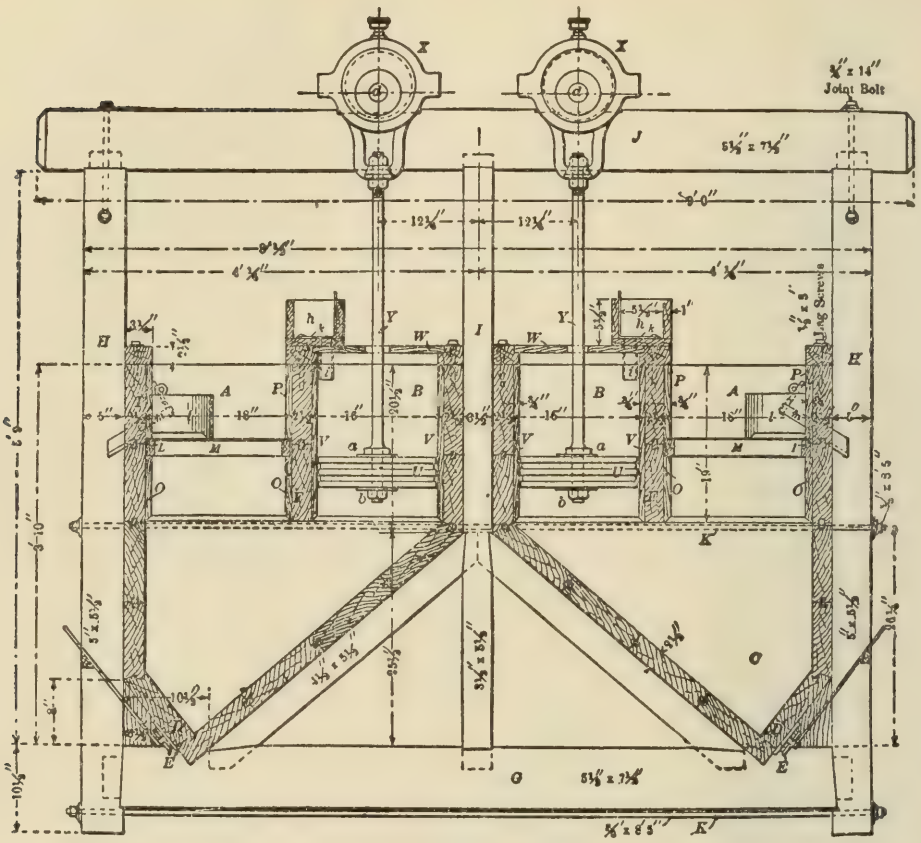


Fig. 32

THE HARZ JIG.

Fig. 32 represents the Harz Jig. We come now to the study of the effects of improved classification upon the different machines, and we will first take up the Harz Jig and call attention to the fact that this jig has a plunger which falls and rises and as it does so it first sends a pulsion of water up through the grains of sand, causing the same action as the hindered settling classifier; and second, the water goes down through the bed of sand sucking down into the hutch the fine grains which are lying in the interstices of the quartz.

Figure 33 represents the curve of a Harz Jig where the movement up and down of the plunger is by simple eccentric, and these curves represent in vertical direction the distance up and down of the movement and in horizontal direction the time elapsing while the movement is made. The curve marked *P*

represents the movement of the plunger, and the curve marked *W* represents the movement of the water; *R* the movement of the rock or quartz, and *O* the movement of the ore or heavy mineral. It is supposed to have moved from left to right, so that the left hand side of the curves represents the pulsion or rising current of water, the right hand side represents the suction or downward rush of water.

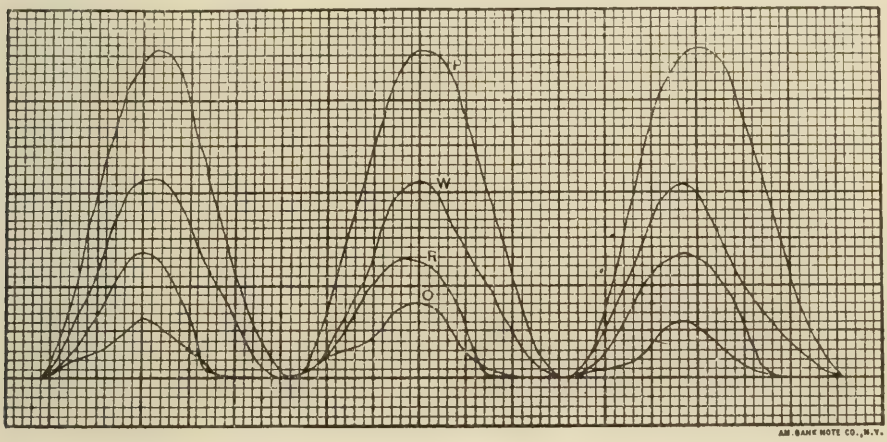


Fig. 33

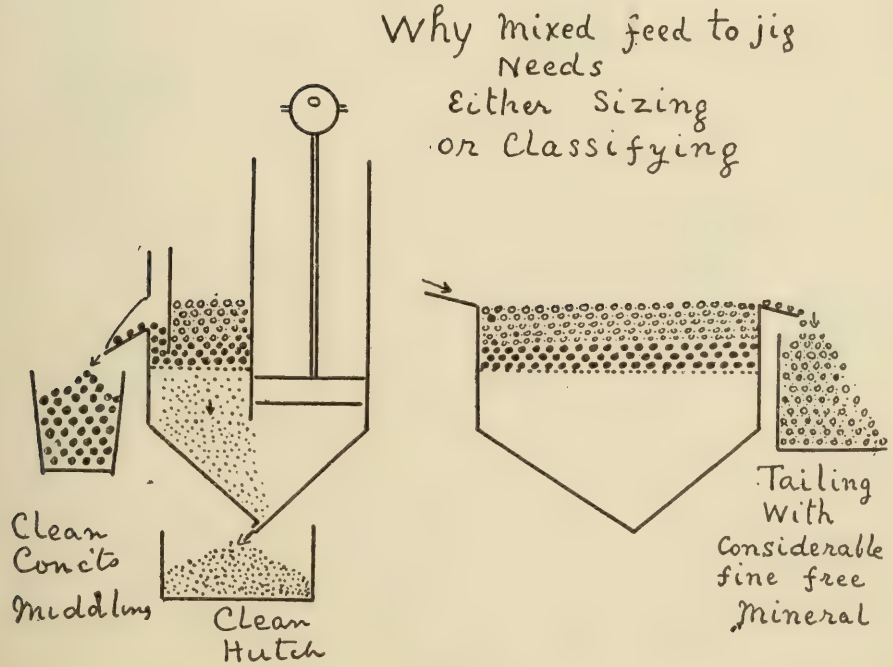


Fig. 34

JIGGING MIXED FEED.

Figure 34 shows points of strength and of weakness in jigging mixed sizes upon a Harz Jig. It can yield a large quantity of good concentrates in the side discharge, it can yield a large quantity of clean hutch work in the grains which pass down through the sieve, but it fails in the fact that the tailings carry a large amount of fine free mineral, which is too fine to be drawn down into the hutch by the suction of the plunger.

JIGGING SIZED FEED.

Figure 35 shows the improvement in jigging that is brought about by jigging a sized product. Here the side discharge is clean concentrates. The amount of hutch is extremely small, and consists of the particles abraded from the ore on the jig bed. The tailings are free from fine free mineral. They probably have included grains, and if so may require recrushing, but the removal of fine free mineral from them places the jig in the most favorable aspect.

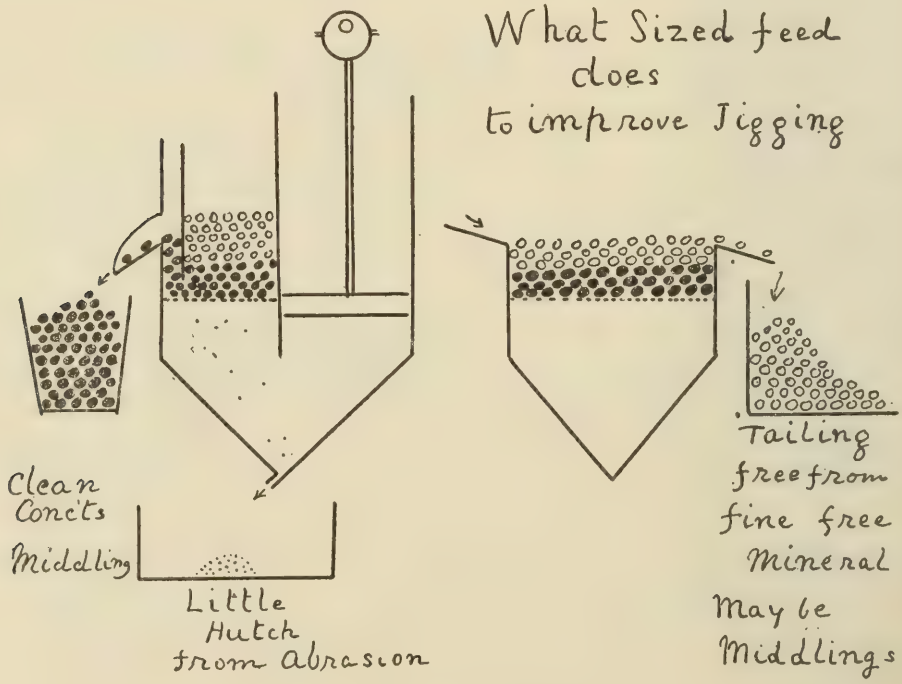


Fig. 35

JIGGING FIRST SPIGOT PRODUCT OF CLASSIFIER.

Figure 36 shows the improvement that may be had by jigging the first spigot product of the classifier. Here the side discharge concentrates and the hutch are both clean and very large in quantity, and the tailings are free from fine free mineral because, while a certain amount of small grains of heavy mineral find their way into the first spigot, they are not small enough to go into the tailings as fine free mineral.

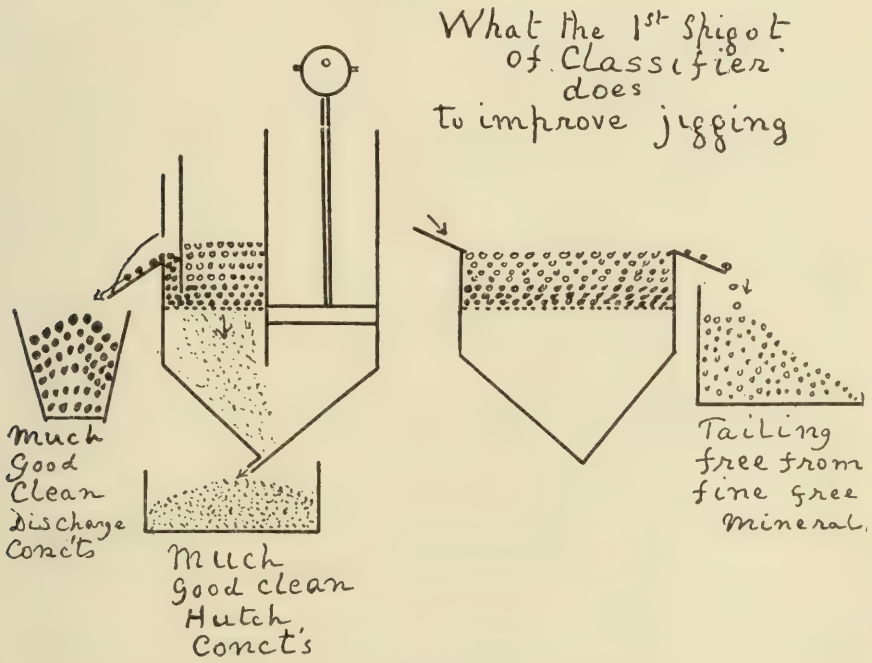

What the 1st Spigot of Classifier does to improve jigging
Much Good Clean Discharge Conc'ts
Much Good clean Hutch Conc'ts
Tailing free from fine free mineral

Fig. 36

JIGGING SECOND SPIGOT PRODUCT.

Figure 37 shows improvement due to second spigot of the classifier. Here the coarse free mineral is all wanting, and, as a result, we simply make hutch work and considerable of it, and this hutch work will be clean concentrates. This jig will require a bed of coarse heavy mineral added to it. The tailings will be free from fine free mineral because, while the grains of heavy mineral are much smaller than the grains of quartz, they are not fine enough to go into the tailings as fine free mineral.

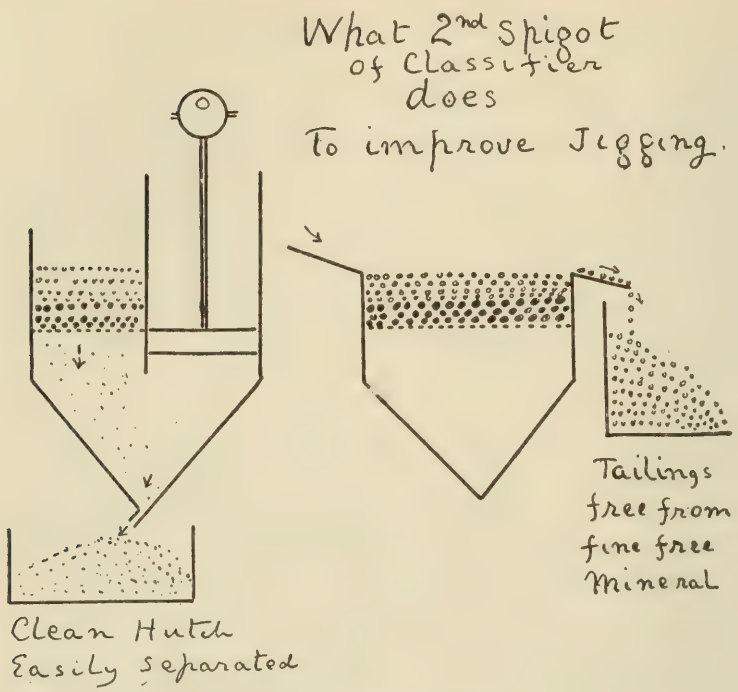

What 2nd Spigot of Classifier does To improve Jigging.
Tailings free from fine free Mineral
Clean Hutch Easily separated

Fig. 37

FREE SETTLING AND HINDERED SETTLING FOR JIG FEED COMPARED.

Why are the two coarsest spigot products of a hindered settling classifier better for jig feed than the two coarsest products of a free settling classifier? *Answer*—The coarsest spigot is much richer and in consequence the jig has less quartz to separate from it, and a larger proportion of heavy mineral is saved from the coarsest product. The next to the coarsest spigot has already had removed from it all the concentrates which go into the automatic side discharge (cup discharge), and the only work left for the jig to do is the suction work of putting the small grains of concentrates into the hutch. For this work a bed of coarse mineral will have to be placed on the jig screen, to prevent the quartz from being sucked down into the hutch. Spigots finer than the two coarsest will ordinarily go to Wilfley table. If the third in size has to go to a jig, what was said of the next to the coarsest will be true of the third also.

Again, in Cycle of the Plunger Jig Transactions A.I.M.E., February, 1896, it is shown that rapid suction and rapid jigging

take place when the ratio of diameters of quartz and heavy mineral is 3.52 or larger. It is also shown that slow suction and slow jogging take place when the ratio of diameters is 2.61 or less.

Taking from Close Sizing Before Jigging the *free settling ratios* for nine inches a second fall, or 228.6 mm. a second, and the hindered settling ratios as obtained from the average of the three columns computed, we have

TABLE 12.

	Free Settling Ratios for 228.6 mm. a second, fastest grains	Hindered Settling Ratios
Copper	3.75	8.598
Galena	3.75	5.842
Wolframite	3.26	5.155
Antimony	3.00	4.897
Cassiterite	3.12	4.698
Arsenopyrite	2.94	3.737
Chalcocite	2.17	3.115
Pyrrhotite	2.08	2.808
Blende	1.56	2.127
Epidote	1.46	2.037
Anthracite	....	5.611

Assuming that 3.52 is the dividing line between easy jigging and difficult jigging with much suction, then we have: Free settling only includes copper and galena as having the favorable ratios, while hindered settling includes copper to arsenopyrite and all the minerals between as having a ratio favorable to suction.

Whether the jig is fed with products from free settling classifier or hindered settling classifier, the tailings will be free from fine free mineral if the classifier is a good classifier and is properly run.

How to Improve Fine Jig Tailings which have resulted from mixed feed. The loss is mostly fine free mineral, and a fine screen will put all this into the undersize, which can go to Wilfley tables. The oversize will be clean waste up to the limit possible. If it has too much included grains it will need to be recrushed.

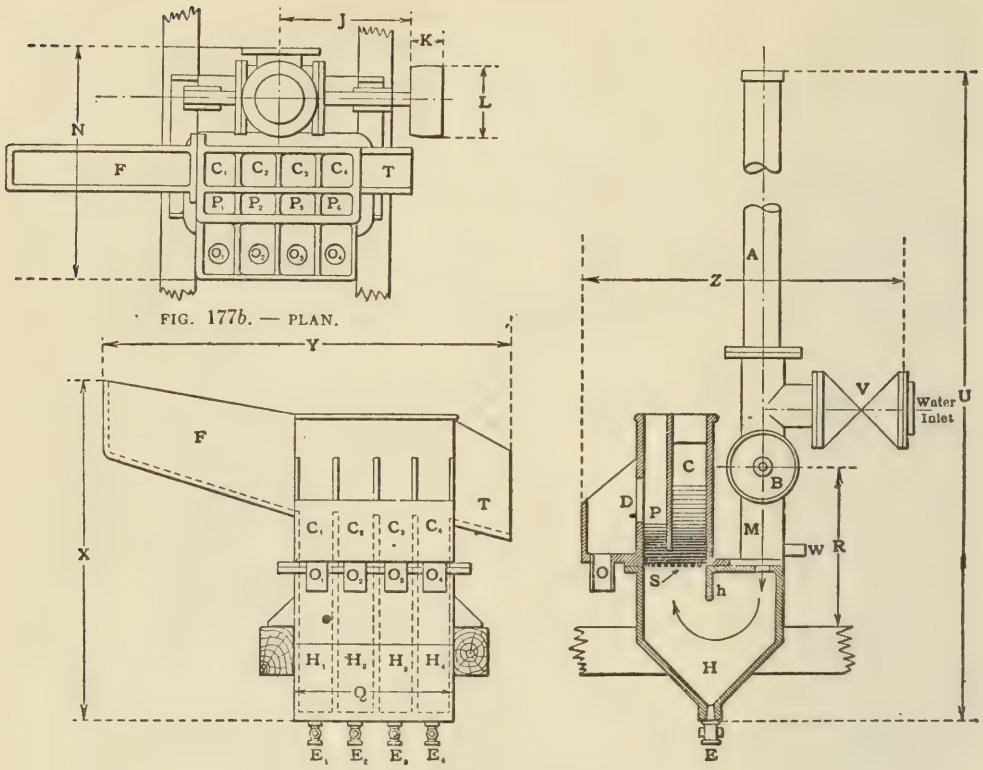


FIG. 177*b*. — PLAN.

Fig. 38

The Pulsator Jig. Figure 38 represents the plan, longitudinal and cross sections of the plusator jig. Here the pulsations given to the sand are from the forward current, due to the opening and closing of the cock, which revolves 100 times a minute, more or less, giving about 200 forward pulsions with an instant of repose between the pulsions. Obviously hutch product is somewhat reduced in this jig, and on that account its main field lies in jigging sized products. If there are small crumblings coming off from the concentrates, due to abrasion, these small grains may find their way into the tailings. If it is used as a machine for treating the first spigot of the classifier, some of the finest grains in this classifier product may find their way into the tailings. This is a disadvantage of the pulsator jig. It is, however, completely. overcome by screening the tailings, in which case the tailings oversize is turned out just as clean as the best Harz jig tailings, while the undersize goes back to classifier and Wilfley tables. The advantages gained by the pulsator jig far more than compensate for the above disadvantage. By omitting the

suction, the matting together of the sands in the bed of the jig, which is so marked in the Harz jig, is avoided, and as a result the jig has a very large capacity for doing work. The mistake one is liable to make, in starting a pulsator jig for the first time, is to cut down the added "hydraulic" water so as to make the upper quartz layer about like that on a Harz jig. When this is done, the bed of heavy mineral below is very hard and immovable. To correct this the quartz bed must be so completely liquified that the bed of heavy mineral is at full teeter below. When this has been done the great capacity of the pulsator jig will be at once available and its ability to control its discharges will also be available. Summing up the advantages of the pulsator jig over the Harz jig, the former requires one-twentieth or less power for driving; it requires, perhaps, one-half the water; it requires less than one-fifth the space in the mill, and the only disadvantage incurred in order to gain these improvements is the necessity for screening the tailings.

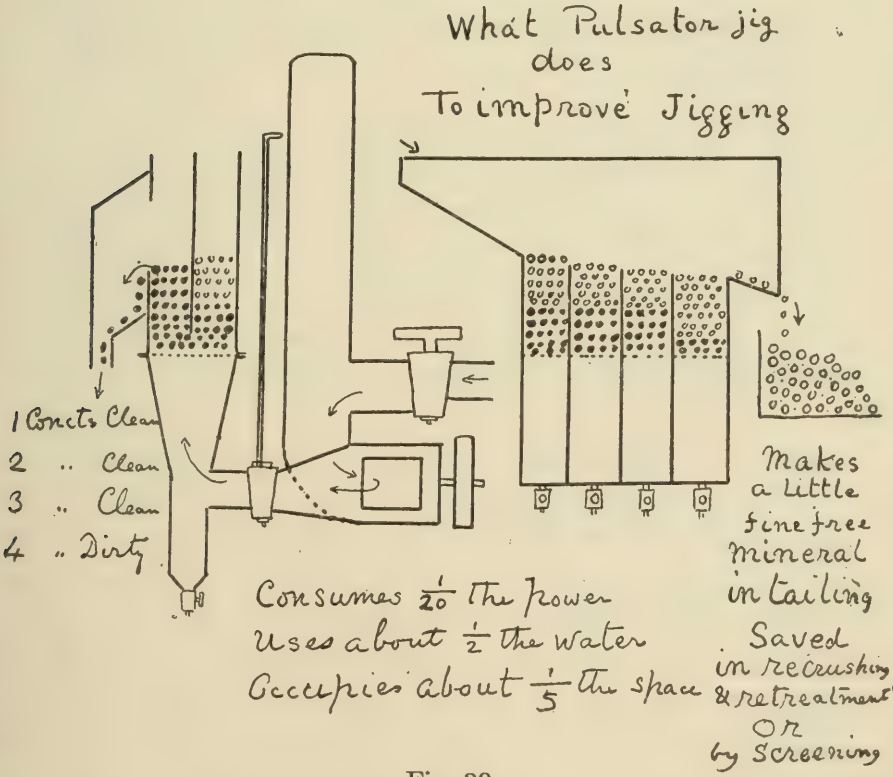

What Pulsator jig does To improve Jigging
1 Concts Clean
2 .. Clean
3 .. Clean
4 .. Dirty
Consumes 1/20 the power
Uses about 1/2 the water
Occupies about 1/5 the space
Makes a little fine free mineral in tailing
Saved in recrushing & retreatment Or by Screening

Fig. 39

Figure 39 represents a pulsator jig making its discharge, concentrates and middlings, and making its tailings with a small quantity of fine free mineral.

Comparing the pulsator jig with the plunger jig, as they have been tested in the mills:—

At Great Falls, Montana, a 4-compartment pulsator jig with compartments four inches square displaced eight plunger jigs with two compartments each and with compartments 19½ inches wide and 39½ inches long. The plunger jigs had 12,324 square inches of sieve, while the pulsator jig had 64 square inches, or, one square inch sieve in the pulsator jig did the same work as 192 square inches in the plunger jig. The pulsator jig tailings were slightly higher in copper, but the plan of screening them to remove the small quantity of fine free mineral had not then been devised.

At Britannia Beach, British Columbia, one 4-inch 6-compartment pulsator jig has replaced five 2-compartment plunger jigs with compartments 24 x 48 inches. The total plunger jig screen area was 11,520 square inches. The total pulsator jig screen area was 96. In this case one square inch of sieve cloth did the work of 120 square inches of sieve in the plunger jig. The results are reported as being quite as good with the pulsator as with the plunger jig.

Feed for Wilfley Table.—The Wilfley table may be fed with (1) mixed feed or natural feed, that is, unclassified and unsized stuff just as it comes from the crushing machine; (2) sized feed which has been screened on 20 mesh, 30 mesh, 50 mesh, 80 mesh and through 80 mesh, or some other suitable series of screens; (3) classified feed prepared by free settling of hindered settling classifier.

Table 12 (Wilfley table, A.I.M.E., July, 1907) shows the results of concentrating a batch of ore with natural feed or mixed feed on a Wilfley table, and table 13 shows the results of feeding classified feed, 2nd spigot, on a Wilfley table. The mixed feed gave for 100 tons of feed 4.1 tons concentrates with 90% galena, 21.5 tons middlings with 23% galena and 72.8 tons tailings with 0.5% galena. The classified feed gave 3.9 tons of concentrates 98% galena, 1.3 tons middlings, 33% galena and 94.7 tons tailings 0.36% galena, showing a great improvement on all three lines above referred to. The above two Tables show many interesting facts and a study of them will well repay the time spent.

TABLE 13.

COMPLETE SIZING-ASSAY TEST OF WILFLEY RUN ON MIXED FEED OR NATURAL FEED.

Size in Millimeters.		Concentrates			Middlings.			Tailings.			Slimes.		
			Assay Percent.			Assay Percent.			Assay Percent.			Assay Percent.	
Through.	On.	Weight Tons.	Galena.	Quartz.	Weight Tons.	Galena.	Quartz.	Weight Tons.	Galena.	Quartz.	Weight Tons.	Galena.	Quartz.
.....	2.06	0.017	100.00	0.00	0.132	73.47	26.53	3.777	0.40	99.60	.....	.....	.....
2.06	1.63	0.059	99.77	0.23	0.795	75.39	24.61	14.713	0.40	99.60	.....	.....	.....
1.63	1.44	0.066	99.80	0.20	0.783	69.47	30.53	11.145	0.50	99.50	.....	.....	.....
1.44	1.27	0.112	99.88	0.12	1.202	62.80	37.20	8.085	0.20	99.80	.....	.....	.....
1.27	1.10	0.084	99.76	0.24	0.954	54.75	45.25	6.174	0.01	98.99	.....	.....	.....
1.10	0.97	0.120	99.43	0.57	1.056	43.80	56.20	7.322	0.02	99.98	.....	.....	.....
0.97	0.84	0.174	98.42	1.58	1.552	31.40	68.60	5.191	0.00	100.00	.....	.....	.....
0.84	0.68	0.206	96.54	3.46	2.021	20.10	79.90	3.350	0.00	100.00	.....	.....	.....
0.68	0.57	0.245	94.47	5.53	1.865	16.70	83.30	2.078	0.00	100.00	.....	.....	.....
0.57	0.45	0.506	91.05	8.95	3.112	11.30	88.70	2.501	0.00	100.00	.....	.....	.....
0.45	0.36	0.402	83.81	16.19	2.326	8.11	91.89	1.581	0.08	99.92	0.156	0.00	100.00
0.36	0.28	0.445	81.24	18.76	2.526	6.44	93.56	1.056	0.12	99.88	0.047	10.20	89.80
0.28	0.24	0.306	81.01	18.99	0.848	4.92	95.08	0.523	0.69	99.31	0.036	10.00	90.00
0.24	0.20	0.375	84.39	15.61	1.230	3.68	96.32	0.633	1.24	98.76	0.053	10.81	89.19
0.20	0.15	0.307	89.48	10.52	0.648	4.44	95.56	0.739	1.45	98.55	0.063	12.58	87.42
0.15	0.12	0.209	95.08	4.92	0.207	6.65	93.35	1.139	1.82	98.18	0.052	19 00	81.00
0.12	0.10	0.110	95.08	4.92	0.075	7.26	92.74	0.624	2.88	97.12	0.068	24.28	75.72
0.10	0.08	0.189	97.74	2.26	0.061	32.23	67.77	0.948	3.43	96.57	0.134	27.04	72.96
0.08	0.00	0.182	99.45	0.55	0.093	90.46	9.54	1.277	7.50	99.49	0.935	28.31	71.69
Total Tons ..		4.114	90.08	9.92	21.486	23.58	76.42	72.856	0.51	82.50	1.544	18.90	81.10

TABLE 14

COMPLETE SIZING-ASSAY TEST OF WILFLEY RUN ON CLASSIFIED FEED

Size in Millimeters.		Sizing Test of Feed.			Concentrates.			Middlings.			Tailings.		
		Per cent.			Weight Tons.	Assay Per cent.		Weight Tons.	Assay Per cent.		Weight Tons.	Assay Per cent.	
Through.	On.	Quartz.	Galena.	Middlings.		Galena.	Quartz.		Galena.	Quartz.		Galena.	Quartz.
2.83	2.49	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.043	0.00	100.00
2.49	2.06	1.517	.....	.....	.....	.....	.....	0.001	0.00	100.00	1.336	0.00	100.00
2.06	1.63	20.299	.....	0.006	0.001	100.00	0.00	0.015	8.84	91.16	18.429	0.08	99.92
1.63	1.44	20.805	0.004	0.009	0.001	100.00	0.00	0.026	10.87	89.13	21.674	0.07	99.93
1.44	1.27	19.856	0.003	0.013	0.002	93.10	6.90	0.037	21.33	78.67	20.207	0.48	99.52
1.27	1.10	15.746	0.004	0.016	0.002	91.45	8.55	0.014	28.29	71.71	11.066	0.09	99.91
1.10	0.97	5.161	0.006	0.011	0.002	89.69	10.31	0.018	39.39	60.61	7.877	0.18	99.82
0.97	0.84	5.925	0.037	0.023	0.011	95.63	4.37	0.078	38.92	61.08	7.835	0.18	99.82
0.84	0.68	2.734	0.063	0.017	0.036	96.15	3.85	0.120	29.42	70.58	2.676	0.54	99.46
0.68	0.57	1.527	0.147	0.013	0.124	97.49	2.51	0.194	25.14	74.86	2.098	1.16	98.84
0.57	0.45	1.558	0.865	.....	0.730	98.01	1.99	0.494	31.00	69.00	1.122	6.04	93.96
0.45	0.36	0.217	0.678	.....	1.208	98.80	1.20	0.188	47.93	52.07	0.121	16.00	84.00
0.36	0.28	0.107	1.215	.....	0.687	98.24	1.76	0.089	49.53	50.47	0.097	33.05	66.95
0.28	0.24	0.028	0.517	.....	0.384	98.96	1.04	0.014	46.20	53.80	0.038	27.60	72.40
0.24	0.20	0.015	0.414	.....	0.393	99.35	0.65	0.011	52.99	47.01	0.024	19.00	81.00
0.20	0.15	0.009	0.233	.....	0.223	99.58	0.42	0.003	71.90	28.10	0.019	13.32	86.68
0.15	0.12	0.005	0.107	.....	0.084	99.81	0.19	0.002	88.22	11.78	0.014	15.30	84.70
0.12	0.10	0.003	0.025	.....	0.021	99.82	0.18	0.001	92.04	7.96	0.009	40.40	59.60
0.10	0.08	0.005	0.029	.....	0.029	99.83	0.17	0.001	91.95	8.05	0.029	55.55	44.45
0.08	0.00	0.009	0.023	.....	0.021	99.64	0.36	0.001	96.40	3.60	0.029	87.00	13.00
Total Tons ..		95.526	4.370	0.108	3.950	98.62	1.38	1.307	33.95	66.05	94.743	0.36	99.64
Settling ratio			4.11										

MR. TSE'S TEST.

Mr. Tse has demonstrated all the above points and done so quantitatively. His test (Fig. 40) was to start the table working upon mixed feed of quartz and galena from 2 .0 mm. to 0 mm. and, when running perfectly, to slip in thirty little trays 1 inch wide in such position as to catch all the products except the finest slimes; as soon as the trays were nearly full they were pulled out and the time in seconds to make the catch noted. These thirty products were then sized on a series of sieves.

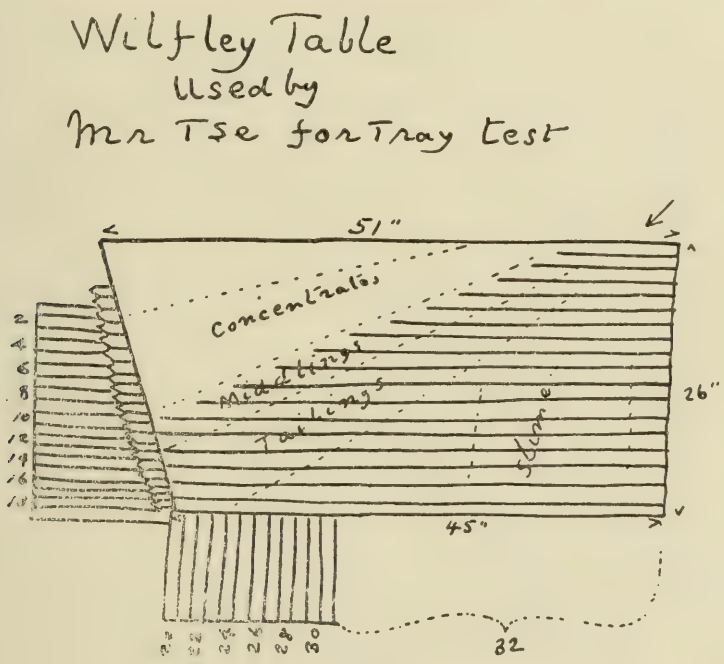


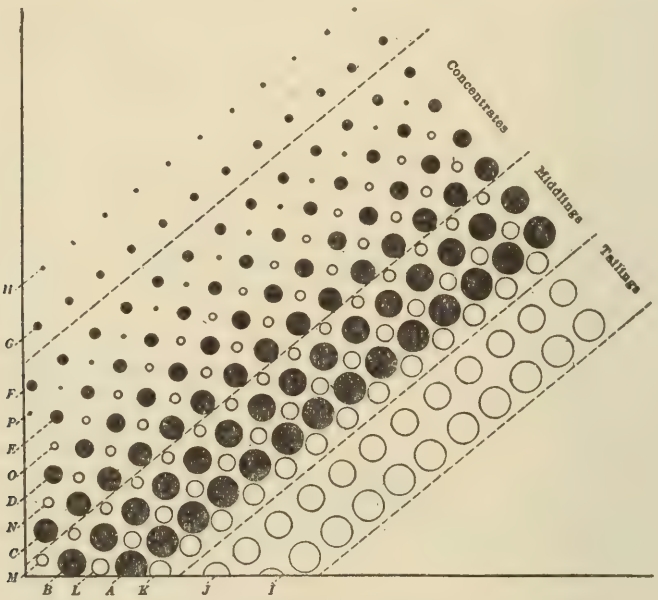
Fig. 40

Trays 10, 11 and 12 (see Fig. 41) are the middlings. In these we can readily see the coarse galena mixed with small quartz in sufficient quantity to very nearly bury the galena out of sight. Looking at the concentrates, we do not see in the photograph the small quartz, but it was found in considerable quantity and was bounded by the triangle whose angles are on the three heaps defined as follows.

(1) Tray 9 sieve .28, (2) tray 5 sieve .20, and (3) tray 9 sieve .12. The fine free mineral of the tailings is partly visible on the photograph. It is shown on line "through sieve .08" from tray 13 to tray 24 or further.

MIXED FEED FOR WILFLEY TABLE.

By studying the diagram Fig. 42, of the bands of mineral grains, where the table was fed with mixed feed with the understanding that the line *H* represents the fine heavy mineral that washes over into the slime, the line *G* represents the fine free mineral that washes over into the tailings, we see that the following irregularities take place which need to be corrected:



—IDEAL SKETCH OF THE ARRANGEMENT OF GRAINS BY A WILFLEY TABLE.

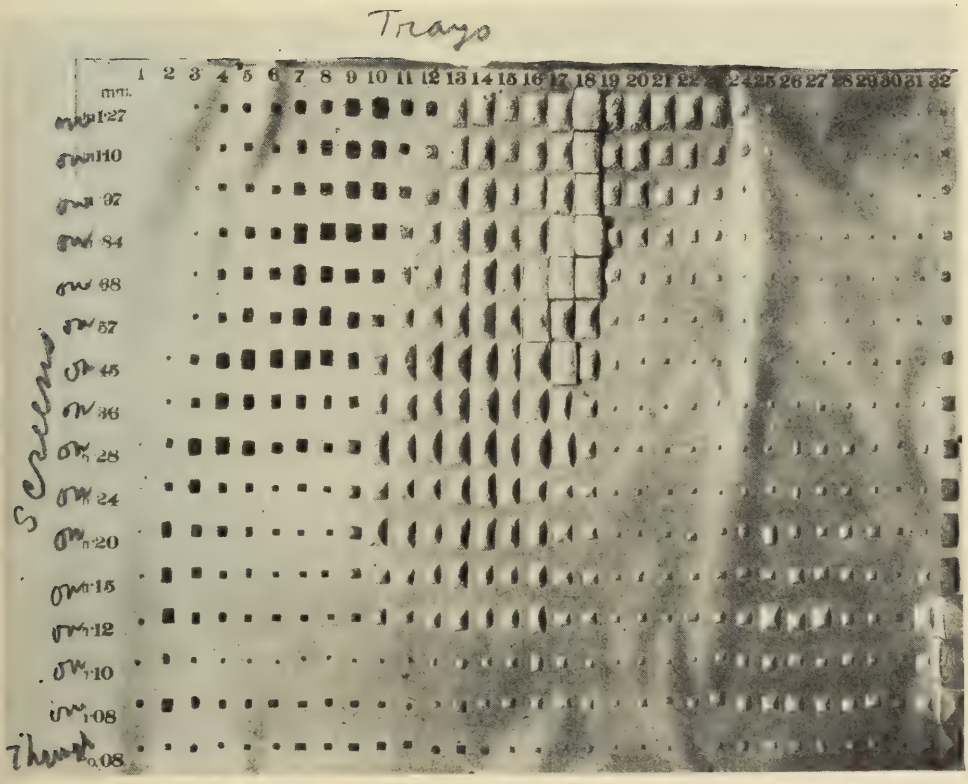
Fig. 42

(1) The concentrates are contaminated by a noticeable amount of small free quartz grains.

(2) The middlings are large in quantity and they have large free mineral mixed with small free quartz and fine free mineral. Mr. Caetani has given the name "counter-classified" where the heavy mineral is in large grains and the quartz is in small grains.

(3) The tailings are contaminated with fine free mineral.

How Sized Feed helps a Wilfley Table.—In the diagram Fig. 43, we have placed the coarse quartz and the coarse galena just where they would be found in mixed feed bands. The actual figures obtained figured for 100 tons sized feed, gave 6.5 tons concentrates with 99% galena, 1.6 tons middlings with 59% galena, and 91.8 tons tailings with .04% galena. It is not probable that the bands will stray so far apart as shown in the figure,


Trayo
mm.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 24 25 26 27 28 29 30 31 32
1·27
1·10
·97
·84
·68
·57
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·36
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·20
·15
·12
·10
·08
·08
Screens
Thumb

Fig. 41

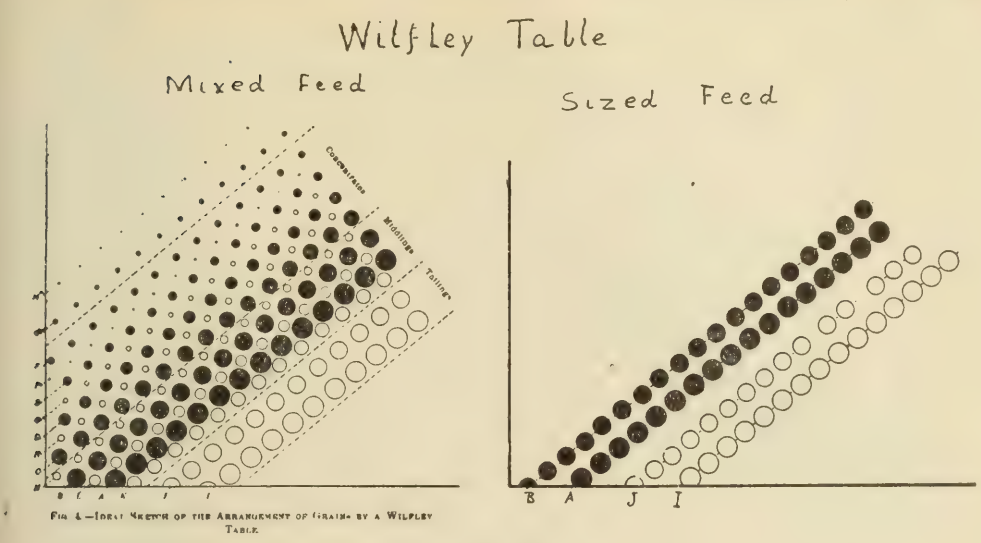

Fig. 43

in fact they will run together a little. The small lot of middlings produced were 1.6 tons with 59% galena, and these grains are perfectly separable on a Wilfley table. In consequence, this middling can go to the little raff wheel and be sent back into the feed without any harm whatever; it will not accumulate unless included grains or middle weight mineral are present. Then different provision will have to be made. Summing up, we have:

The concentrates are free from small quartz;

The middlings are small in quantity and can be fed over again unless included grains or middle weight mineral is present;

The tailings are free from fine free mineral; all of which is as satisfactory as possible.

How First Spigot of a Classifier helps a Wilfley Table.—In the diagram Fig. 44 we have placed the coarse quartz and the small galena together, with the added increment of larger galena approximately where they would be found in mixed feed bands. If actually drawn to a scale the band of galena would be much wider than is shown in this diagram. They will not stay so far apart, but will mix a little. In my test, the middlings ran up to 5.5 in 100, but that, I think, is unnecessarily high. These middlings, unless included grains or middle weight mineral are present, can be returned and fed over by raff wheel, and so save

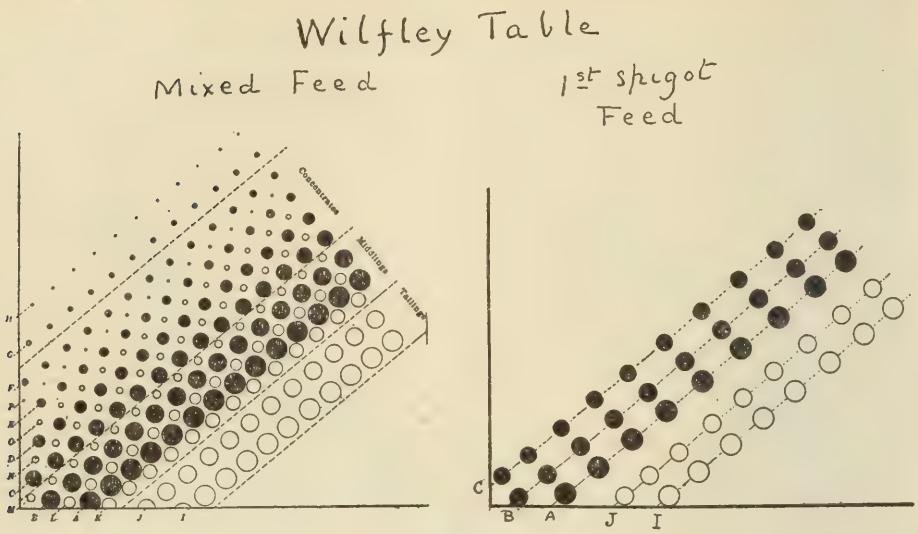

Fig. 44

further complications. The actual figures obtained and rated for 100 tons feed were: concentrates, 49.6 tons with 99% galena; middlings, 5.5 tons with 13.8% galena; and tailings, 44.8 tons with .29% galena; all of which is a thoroughly satisfactory improvement over mixed feed. The concentrates are free from quartz, the middlings are small in quantity, the tailings are practically free from fine free mineral.

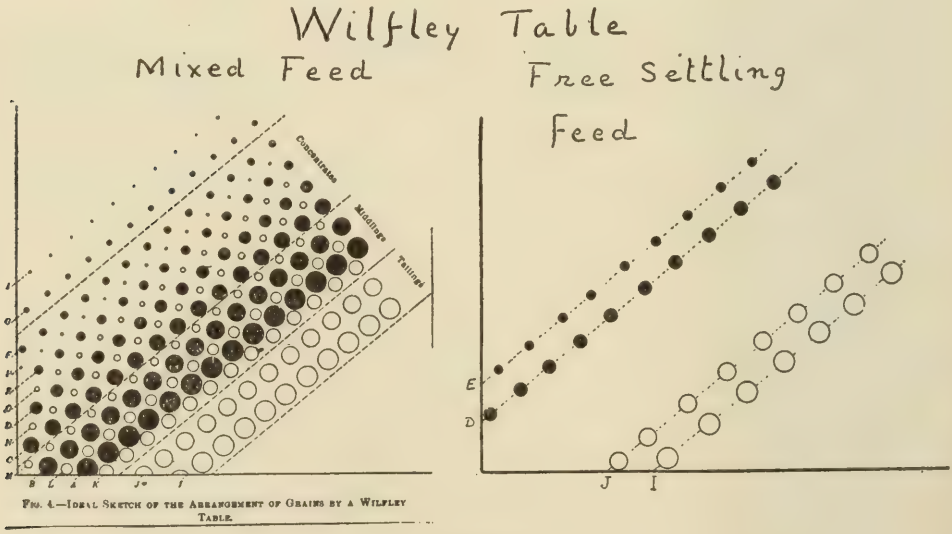

FIG. 4.—IDEAL SKETCH OF THE ARRANGEMENT OF GRAINS BY A WILFLEY TABLE.

Fig. 45

How Free Settling Second Spigot helps a Wilfley Table.—Here see diagram 45) the bands are placed far apart, as they would

be in the mixed feed diagram. If actually drawn to scale they would be farther apart than as shown in this figure and the galena grains would be smaller relatively to the quartz. The actual figures obtained on a basis of 100 tons were. concentrates, 3.9 tons 98.6% galena; middlings, 1.3 tons, 33.9% galena, tailings, 94.7 tons with .36% galena. Here again the concentrates are practically free from small quartz, the middlings are small in quantity, and the tailings are almost free from fine free mineral.

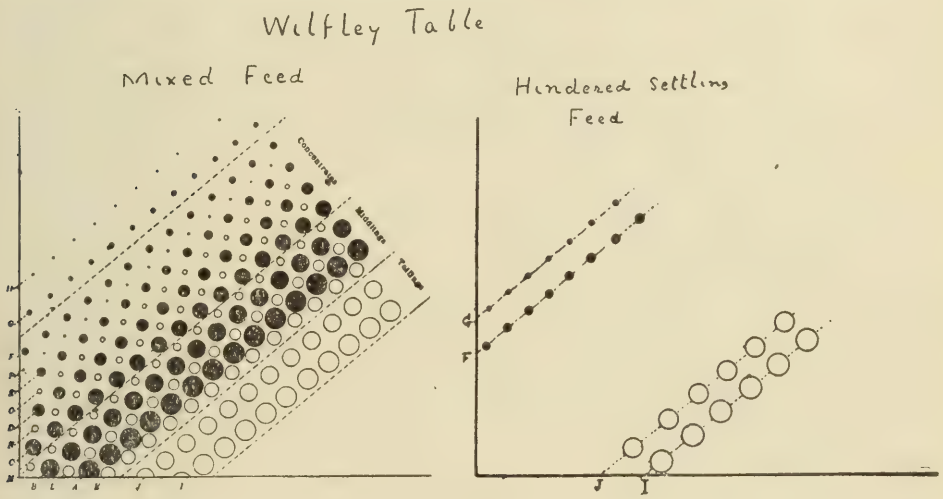

Fig. 46

How Hindered Settling Second Spigot helps a Wilfley Table.—The diagram (see Fig. 46) represents the quartz and galena bands approximately as they would occur on the mixed feed table. They are probably not far enough apart even here if drawn to scale. In actual work these will drift towards one another and be slightly mixed in the middlings; but the middlings can be fed back as in the previous cases and disappear from the account, unless they are contaminated by included grains or middle weight mineral, in which case they must receive suitable consideration, as in the previous cases also. (This calls for another paper.) My paper in Trans. A.I.M.E., July, 1907 on Wilfley Table, has no instance in it of hindered settling feed. (This calls for another paper.)

A Geometrical Suggestion.—When one watches the coarser tailings on the margin of the bands on a Wilfley table, namely, the jerk forward, due to the mechanism, and sees that the grains are jerked forward a little and then drop over a riffle cleat, then

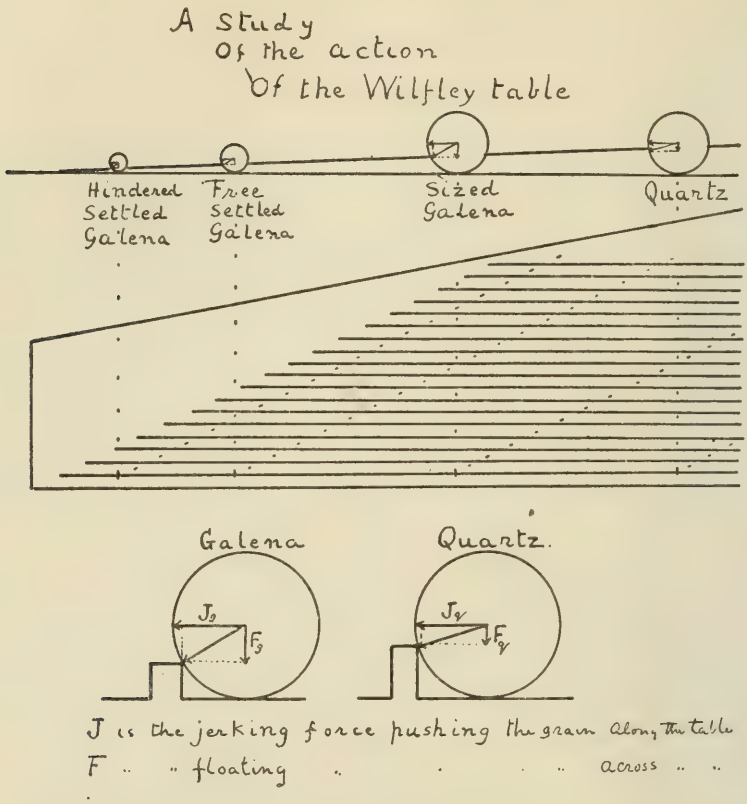

Fig. 47

jerked forward again, and then drop over a riffle cleat again, he is led to ask what is the determining feature which causes the grain to be lifted over the cleat. Figure 47 is offered as a suggestion pointing to cause and effect. The large quartz grain has a short vertical arrow representing gravity, and a longer horizontal arrow representing the force of the water. Between these two forces lies the diagonal of the parallelogram which is the resultant of the two forces. The action would be as follows:—As soon as a point on the taper riffle cleat was reached where the resultant came above the cleat, that moment the grain would rise over the cleat and drop into the next groove. This could be repeated over and over, and thus give the path of the quartz grain down a diagonal. The sphere of galena of the same size as the quartz would have a longer vertical arrow and therefore its diagonal would reach lower, and therefore the riffle cleat would have to be considerably lower before the point was reached where the galena grain could rise over and drop into the next groove. This gives the large grain of galena a diagonal path considerably

in advance of the quartz. Again, a galena grain related in diameter to the quartz, as in the second spigot of a free settling classifier, that is with a ratio of 1 is to 3.5 in diameter, could be far in advance of the equal-sized grain of galena. Finally, galena grain related in diameter to the quartz, as in the second spigot of a hindered settling classifier, that is with a ratio of 1 to 6.9 would be still further in advance of the quartz. This cannot be regarded as a demonstration, because the grains in the figure are far too large to be true to nature; but if we consider that the vertical arrow represents the sum of all the forces that tend to keep the grain in the groove, and the horizontal arrow represents the sum of all the forces pushing the grain down the slope, then this analogy may turn out to be a true picture of fact.

What can be done to improve Wilfley Table Middlings resulting from mixed feed supposing no preparatory classification is used. This product is "counter classified" with grains of heavy mineral larger than the grains of quartz. (See Fig. 41, trays 10, 11 and 12; see also Fig. 42). It can be screened to let the small quartz and fine heavy mineral go through while the coarse heavy mineral remains on the screen as oversize or, better, it can be fed to a little free settling classifier with one pocket. This would save more of the heavy mineral than the screen or, best of all, it could be fed to a one pocket hindered settling classifier which would save more heavy mineral than the little free settling classifier. The rejected fine product with either method could go to a Wilfley table to finish it.

What can be done to improve Wilfley Table Tailings resulting from mixed feed with no preparatory classification. This product has included grains and fine free mineral. I am assuming that the slime has been already separated from it. This product is the exact opposite of the middlings. Free settling classifier is better than hindered settling and screen sizing is better than free settling. The Callow Screen seems to be the machine for this work. The oversize will in all probability be clean enough to throw away, if not it must be crushed for included grains. The undersize can go direct to a vanner and yield clean concentrates and tailings. The slime can be sent to a vanner unless another slimer has been proved to be better.

What can be done to improve Vanner Tailings resulting from mixed feed without preparatory classification. A vanner feed

with pulp .847 mm. to 0 mm. (See Fig. 48) will yield in the concentrates pyrite .847 to .0706 mm. diameter and in the tailings quartz .847 to 0 mm. with pyrite .0706 mm. to 0 mm. This .0706 mm. is only the result of a single determination and needs to be corroborated; but it is believed to be about right. Here as in Wilfley tailings hindered settling is not so good as free settling and free settling is not so good as sizing for separating the fine from the coarse.

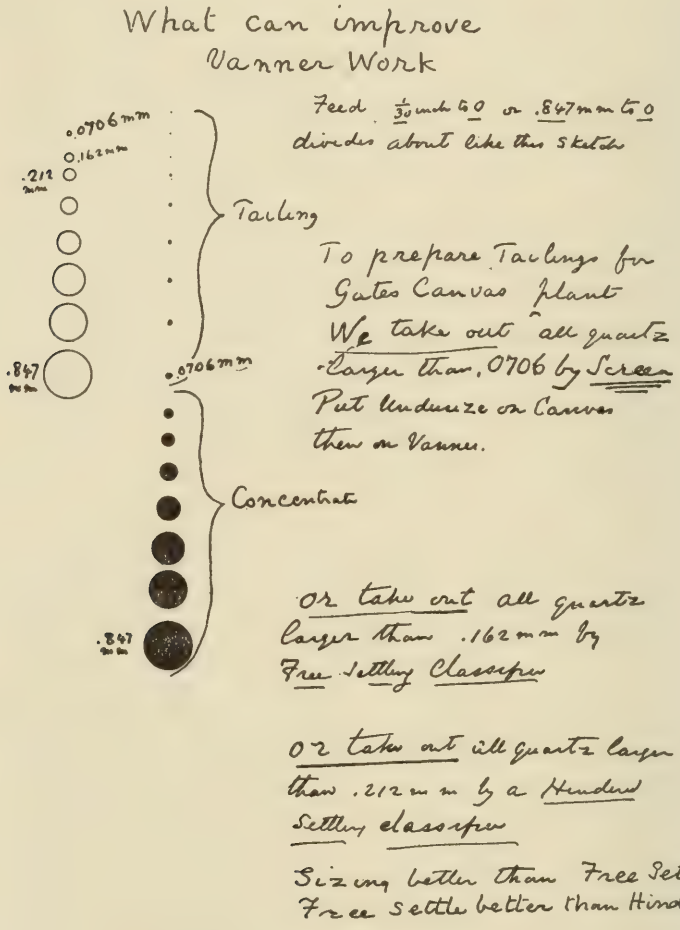

Fig. 48

Hindered settling would put into the overflow (multiplier is about 3):

Pyrite .0706 to 0 mm.
Quartz .2118 to 0 mm.

Free settling would put into the overflow (multiplier is about 2–25):

Pyrite .0706 to 0 mm.
Quartz .1588 to 0 mm.

Screen sizing would put into the undersize:

Pyrite .0706 to 0 mm.
Quartz .0706 to 0 mm.

Clearly the screen is theoretically the best but the process would call for such a fine screen that it would, according to present knowledge, probably be impossible.

Having obtained the overflow or undersize we next feed it upon a canvas table making clean tailings and feed the canvas concentrate on a steep high speed vanner making clean concentrates and tailings to go back to canvas.

CAUSES OF VARIATIONS IN ORE SAMPLING.*

By THOMAS KIDDIE, Northport, Wash.

(Nelson Meeting, Sept., 1909).

There are a number of approved mechanical ore samplers in use, each kind having its own advocates, but so far as I am aware, there is not any regular nor standard method of determining the accuracy, or otherwise, of these machines.

In sampling, ordinarily, the personal element enters to some extent. A certain make of sampler is recommended and installed; and generally, there being no other sampling machine in use in the same establishment, those using it have no effective means of checking it against one of another style or make. As a consequence, the interests of both buyer and seller of the ores sampled are affected by the results obtained by such sampling, either adversely or favourably, as the case may be, through possible inaccuracy.

In my opinion, tests to determine the accuracy of all samplers and sampling methods should include sizing tests as well as chemical tests, instead of, as by the present method of chemical tests only; and if as I believe it can be proved they do, the values of the different portions of an ore increase or decrease more or less consistently with the size of the particles in the portions tested, then it follows that the machine or method of sampling, which shows the least variation on analysis by sizing, gives the most accurate sample.

In the course of experiments made on the separation of metallic sulphides from silicates (or quartz) by the gradual crushing of sulphide ores, having a hard gangue, from three and a-half to three-eighths inch approximately, it was found that the pro-

* Preliminary notes.

portions of certain constituents in those ores always increased, and certain other constituents always decreased as the size of the portion tested increased, as shown by the following tables of analysis and sizing tests:—

	Original Ore.	On $\frac{3}{8}$" screen.	On $\frac{1}{8}$" screen.	On 30 mesh.	On 80 mesh.	On 120 mesh.	Thro' 120 mesh.
Au. Oz.	0·22	0·22	0·20	0·18	0·38	0·43	0·24
Ag. Oz.	0·50	0·50	0·50	0·50	0·70	0·80	1·00
Cu. %	1·12	0·81	1·09	1·39	1·66	2·19	2·13
Fe. %	15·50	16·40	18·00	17·60	20·10	24·80	23·60
SiO. %	44·70	45·90	45·50	45·00	39·60	34·20	34·40
S. %	4·80	5·00	3·60	5·20	8·20	11·20	9·30
CaO. %	7·20	7·10	6·20	8·40	7·70	7·10	7·40
AlO. %	16·80	19·60	18·10	15·80	13·40	13·10	14·20
Sizing test % by weight.	100·0	78·25	11·00	7·68	1·25	0·34	1·48

From the above, it will be seen that the percentage of silica and alumina increases with the size of the ore, although not apparently in accordance with any definite mathematical law, and that the gold, silver, copper, iron, and sulphur decrease as the lumps are larger. This was confirmed by the following analysis as to composition and size:

	Original ore.	On $\frac{3}{8}$" screen.	On $\frac{1}{8}$" screen.	Thro' $\frac{1}{8}$" screen.
Au.	0·29	0·14	0·25	0·32
Ag.	0·60	0·40	0·60	0·80
Cu.	1·46	1·19	1·50	1·46
Fe.	16·10	13·40	17·60	18·10
SiO.	46.20	48·90	46·40	42·00
S.	4·20	3·60	4·60	6·80
CaO.	7·40	8·20	7·70	7·40
AlO.	17·20	21·10	16·60	15·40
% by weight.	100·00	70·50	11·00	18·50

A third lot of ore, rough, but all under $3\frac{1}{2}$ in. in size, was screened over a $\frac{1}{2}$ in. screen; the following analysis of the original and roughs, respectively, will serve to further illustrate and confirm these conclusions:—

	Original Ore.	Roughs.
Au. Oz.	0·30	0·15
Ag. Oz.	0·70	0·40
Cu. %	1·31	0·76
Fe. %	16.00	13·20
SiO %	45·40	47·20
S. %	4·70	3·10
CaO %	7·40	8·30
AlO %	17·20	18·20

Applying this principle to the sampling of ores, it would appear that analysis by sizing should prove the accuracy or otherwise of any sampling device. With this purpose in view, a Jones' ore sampler, 10 in. size, fed with an ordinary mill sample, was tested, with the result that the proportions of the respective sizes shown in the next following table were discharged from opposite sides of the sampler, the total quantity of ore passed through the machine during this test having been 3,016·5 oz:—

Screens.	Side A.		Side B.	
	Weight in oz.	Percentage.	Weight in oz.	Percentage
Thro' ½″ on ⅜″	824·50	56·319	855·50	55·105
Thro' ⅜″ on ¼″	247·75	16·923	280·50	18·068
Thro' ¼″ on 1–16″	198·25	13·541	205·25	13·221
Through 1–16″	193·50	13·217	211·25	13·606
Total	1464·00 = 48·53%	100.00	1552·50 = 51·46%	100·00

This shows a variation between the two sides of the sampler of 88 oz. or 2·932%, and between the respective sizes, as follows:—On ⅜ in. screen, 31 oz.; on ¼ in. screen, 32·75 oz.; on 1/16 in. screen, 7 oz., and through 1/16 in. screen, 17·75 oz.

The results of this test indicate one very serious source of error, which may occur in determining the actual values of ores sampled by a riffle sampler.

As further showing the variation in sampling, the following figures are submitted as a result of a test to determine the differ-

ence between a sampling by riffle and cone methods, respectively, with 300 lbs. of ore riffled down to 50 lbs.:—

	Riffle %.	Cone %.	Difference %
Number 1.			
Thro' ½″ on ⅜″ screen	29·84	26·32	3·52
Thro' ⅜″ on ¼″ "	36·62	32·61	4·01
Thro' ¼″ on 1–16″ screen	17·42	26.18	8·76
Through 1–16″ screen	16·12	14·89	1·23
Number 2.			
Thro' ½″ on ⅜″ screen	7·9	8·23	0·4
Thro' ⅜″ on ¼″ "	18·7	19·1	0·4
Thro' ¼″ on 1–16″ screen	40·9	40·8	0·1
Thro' 1–16″ on 20 mesh screen	15·8	15·6	0·2
Thro' 20″ on 40 mesh screen	9·1	8·5	0·6
Thro' 40 mesh screen	7·6	7·7	0·1

The following show variations in cone samples:—

	A. %	B. %	Difference.
Thro' ½″ on ⅜″ screen	2·1	3·4	1·3
Thro' ⅜″ on ¼″ "	11·8	16·0	4·2
Thro' ¼″ on 1–16″ screen	43·8	44·3	0·5
Thro' 1-16″ on 20-mesh screen	17·5	16·0	1·5
Thro' 20 on 40-mesh screen	12·4	10·2	2·2
Thro' 40-mesh screen	12·4	10·1	2·3
	C.%	D.%	
Thro' ½″ on ⅜″ screen	4·8	5·4	0·6
Thro' ⅜″ on ¼″ "	17·2	21·4	4·2
Thro' ¼″ on 1–16″ screen	44·0	42·2	1·8
Thro' 1–16″ on 20-mesh screen	15·5	14·0	1·5
Thro' 20 on 40-mesh	10·1	8·9	1·2
Thro' 40-mesh screen	8·4	8·1	0·3

From the chemical analysis of the ore, and from the sizing tests contained in the foregoing tables, it is clearly shown that there are great differences in the metallic contents of the various sized particles, and results obtained vary considerably with the present methods of sampling.

It is, therefore, necessary that a sampler, or method of sampling, shall deliver the exact proportion of the different sizes contained in the ore sampled, and that in order to do this the personal element must be eliminated

To prove the accuracy of a sampling machine or of any method of sampling, it would be necessary to make up a synthetic

or artificial ore, by taking several weighed and previously assayed quantities of different sized particles, and then mixing them so as to make up an ore, the composition of which, as regards the sizes and contents of its component particles, is known. The whole of this artificial ore would be passed repeatedly through the sampling machine, and each sample thus obtained would then be passed through the same screens used in making up the ore, and the proportions of its several sizes be determined and compared with that of the original.

It would seem to me advisable that these determinations should be undertaken by a commission, or, as a preliminary step to that end, by the faculty of some school of mines or other like institution.

If this were done, and similar tests applied to all well known makes of sampling machines, we would then have absolute data, obtained from a competent and independent source, whereas the results already published are usually those from one class of machine only.

It must be remembered that this investigation applies to one class of ore only, and that a wide field for investigation along these lines is open to any one sufficiently interested in the matter to enter upon it.

The application of this principle of separation of metallic sulphides, by crushing, has already produced satisfactory results in smelting, by the adoption of such means as was found necessary to prevent such separation taking place, whereby a uniform ore charge was delivered to the furnace, resulting in an increased output and a general betterment in furnace conditions.

Since the above was written, Dr. J. Bonsall Porter, of McGill University, has kindly undertaken certain work in continuing this investigation, which will be made the subject of a future joint paper.

Discussion.

Mr. W. F. Robertson inquired of Mr. Kiddie if the ores referred to in the paper were all of the same class and if they were silicious sulphides, which he understood to be the class of ores chiefly handled at the Northport smelter?

Mr. Kiddie replied in the affirmative.

Mr. Robertson then said, if he remembered rightly, the old Orford ore, with which Mr. Kiddie and he had been familiar years ago, was copper pyrites with mundic, and the fines were poorer than the roughs, instead of richer. This, he thought, emphasized the need mentioned in the paper of great care in preparing the mechanical condition of the ore. The proportions and sizes must be true, or the sample would not be a true sample. He remembered that they required to be very careful at the Orford works to secure the proper proportion of fines, or the sample would be too low in copper. In fact, the general experience seemed almost to indicate the advisability of making sizing the determining basis, without intricate analysis, thus getting a fair check on results. Mr. Robertson then moved a vote of thanks to Mr. Kiddie for his paper on this most important subject, and included in his motion the suggestion that the secretary be instructed to have the tables contained in the paper presented in graphic form. This was seconded by Mr. A. H. Gracey. It was here explained that Dr. J. Bonsall Porter, of McGill University, and a member of the Council of the Institute, who had read Mr. Kiddie's paper, had already undertaken to have the tables produced in graphic form, besides having offered to continue, in conjunction with the writer, the investigation of tests of sampling machines, as recommended in the paper.

Mr. Kiddie said he entirely agreed with Mr. Robertson's remarks. It would be necessary to make tests with other classes of ore. The value in one class might be in inverse ratio to the size and the opposite in another. Similar investigation would be needed for each class of ore. Regarding the question of the sizing test being sufficient to decide the accuracy of a sampling machine, it would be sufficient if the value of the proportionate sizes had been determined. It did not mean that it involved doing away with assaying.

Mr. E. W. Widdowson said it was generally conceded that the sizes of the ore had a great deal to do with its value. In the Slocan ores the fines always carried higher values than the coarse. Much trouble was necessary to get the samples evenly taken, but in hand sampling this was not always done. He had not been

present to hear the whole of the paper read and asked if it suggested any method of taking samples evenly.

MR. KIDDIE then explained the theme of the paper to Mr. Widdowson, who asked if the former knew of any machines that were accurate. Mr. Kiddie replied that many machines were excellent samplers, but the chemical analysis was still required. Proper sizing would determine the accuracy of the machine without the chemical test. By using a synthetic ore the experimenter would know the sizes of the pieces constituting the sample, and the correct proportion of each size put into it. If the values of the component ores had been previously determined, then the sizing test should indicate any variation in the machine-cut sample.

MR. KIDDIE then asked Mr. Gracey to state his experience as to the variation in crushed ore where there was a hard gangue with little or no sulphides, as in Sheep Creek ores. Assuming the ore was broken to half-inch and sized off to 100 mesh, what would he say regarding the distribution of the gold? Would the gold follow the fines or the roughs in the highest percentage?

MR. GRACEY replied that his experience with oxidized ores showed that the fines were richest in gold. His conclusion was based only on rough work, panning, horning, etc., but the fines were always richer than the coarse ore. The value varied in inverse proportion to the size of the particles. He had not experimented with Sheep Creek ores, but could say roughly that the fines are certainly the richer in gold*.

MR. KIDDIE remarked that it was important to have such independent information as Mr. Gracey had given.

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*Regarding the fineness of the gold in the oxidized ore, the following is from the "Journal of the Chemical, Metallurgical and Mining Society of South Africa," July, 1909, p. 16; discussion by J. C. Mance, Singapore, on "The Pilgrims' Rest Gold Fields and Mining Methods:"

"Once, when visiting the Frankfurt mine, to the north of Pilgrims' Rest, I had occasion to take some 15-20 samples in a drive, and the highest value by panning I was able to record was 4 dwts; these samples, when assayed, gave anything from 5 to 18 dwts. to the ton. I was astonished at not seeing gold freely in the pan. The figures I give are from memory, but the occurrence struck me as remarkable, and one not easily forgotten.

"The following from my pocket book, which I happen to have by me, with reference to the gold contents in the oxidized ore, clearly shows where the gold is:

"Mesh used, 900 to the square inch.
"Per cent. of gold in heavy sand..... 7·18
"Per cent. of gold in light sand..... 34·44
"Per cent. of gold in slimes..... 58·38"

MR. WIDDOWSON asked Mr. Kiddie if he conceded that all the particles in a pile passed through, say, a quarter-inch mesh would be of the same relative value.

MR. KIDDIE replied that they would be of the same value approximately, but it could not be said that every particle in that size would be of the same value. His calculation was based on the average.

MR. A. C. GARDE thought that the sizing test might be dangerous when applied to such machines as the Bridgman, where the centrifugal force, engendered by the rotary motion of the machine, would certainly separate the heavy and light ore particles. This objection, he thought, would apply to using the sizing test on any other sampling machine based on speed.

MR. KIDDIE replied that the point he was urging was the necessity for getting a standard means of testing sampling machines and methods. The point raised regarding centrifugal force was an important one, and in the sampling machine with which he was experimenting, he had had to consider this force, and to avoid that particular factor in the sampling.

MR. M. J. CONNOLLY said he had found that the agility of the various particles made a difference in the way they were deposited, and he thought this should be taken into consideration. He had certainly found it necessary to get an even distribution. In making up samples, he had found that the silica would drop down and particles of like agility would go to the same spot. This produced a separation of the lighter and heavier particles.

MR. KIDDIE said that just such perceptible separations as that mentioned by Mr. Connolly made special precautions necessary in smelting. The fines in ore, dropping into a 45 degree inclined bottomed ore bin from above, had a tendency to stay where they fell, while the roughs, bounding forward, and the medium rolling further than the fines, resulted in the separation of the ore into roughs in front, then the medium, and the fines behind. When the ore was drawn from the ore bins the roughs came fast at first. The result was that the furnace would be running for the first hour, or two hours, as the case might be, on an entirely different class of ore than that figured on, which would cause variations in the furnace charge, the same as occurred in sampling. It was by applying these principles and preventing

separation going on that many difficulties in smelting had been overcome. Ores in handling would separate into sizes, the value of which would vary with the size.

Mr. Robertson referring to coning, said that it should be realized that the results depend very largely on the personal factor. Training was important and efforts were often made to eliminate this personal factor. The most successful attempt he had ever seen at this elimination was at Balbach's works. There, in getting rich ores from South America, the system was to place the ore to be sampled in a circle, laying first the pieces large enough to hold the ore to be sampled in a pile a foot high and two feet wide. Two, three, or four men were then placed around the pile, all facing in the same direction. Each man took a shovelful from the pile and deposited it in a certain spot, and then advanced a step before taking another shovelful. In this way each man moved around the pile, never taking a shovelful twice from the same place, thus eliminating the personal factor. The results of two or three repeated samplings showed that this method was very accurate indeed. Thus, sampling by the cone system must be carefully done. Mechanical samplers were of course mechanical and allowed of no personal element.

Mr. Gracey expressed the opinion that in drawing from the centre each man should draw and then move around. All the men would thus have to be in partnership to permit the personal element to interfere. Quite a difference might arise, however, in the quartering.

Mr. Kiddie remarked: "That very personal element is one of the chief troubles." He thought the samples should be cut mechanically and the cone and riffle done away with. The sample should be put into a hopper and ground down. The Braun's pulverizer was ideal, but the pulverizing in itself causes a gradual separation, inasmuch as it separates the valuable particles from the silica. The personal element appeared again in the rolling on a rubber sheet. A man might easily roll it in such a manner as to cause a separation. Might it not be put into a churn and the personal element thus be done away with? Why not put the sample into a machine and cut it into six parts mechanically? It could be done.

MR. ROBERTSON called attention to the fact that, under the old Cornish rule, the man who quartered the cone was not allowed to select the sample to be tested.

MR. JACOBS pointed out that this valuable paper was one of the results of the existence of the Western Branch. He thought Mr. Kiddie would agree with the statement that had there been no Branch the paper would never have been written.

MR. W. H. TREWARTHA-JAMES:—Although the art of sampling is one of the elementary subjects first taught us on entering the mining and metallurgical profession, the more experience we gain the more we find it necessary to investigate and critically analyse the methods of applying the principles which at first we thought so simple and easy.

The author freely admits that the personal element must influence to some extent all sampling operations, but he pleads for a mechanical sampler which shall deliver a sample containing practically the exact proportion of the different sizes contained in the ore sampled, independently of any personal equation. I think we must all cordially agree with him in wishing for this great desideratum. But I am afraid the personal element can never be entirely eliminated in ore sampling, for I regard sampling not as an exact science—as the author and all of us would like to make it—but as an art in which individuality and the human equation must always play its part, the mechanical sampler being still a mere accessory appliance.

This does not in any way lessen the desirability of evolving standard methods which can be applied to checking and testing any form or forms of mechanical samplers, as the author proposes. I myself cordially agree with his general conclusion that as between two different machines which one might choose, that machine which delivered the various sized particles which go to make up an ore, in their correct and relative proportions, would *per se*, and other things being equal, be the more accurate and the more desirable to use.

I have to point out, however, that it does not necessarily follow that any particular mechanical sampler which passed this test would necessarily yield an accurate sample, nor is it necessarily inaccurate because it does not furnish the sizes in their true proportion. This opinion is based on the fact that there is no

reason why any particle or number of particles screened from a parcel of ore to be sampled, and closely sized, should contain the same percentage of the values sought in sampling as any other particle or number of particles of the same size. So that even if any particular sampler delivered two equal portions of ore in exact ratio to the contained sizes, the two portions so obtained would not necessarily contain the same values, particularly in ores where the values are distributed in patches, even when broken to such a size that all contained minerals have been liberated from each other.

I think the main source of inaccuracy in mechanical samplers lies in the conditions under which the feed (that is the material to be sampled) is presented to the machine, in a majority of instances. No matter how accurate the machine might be proven to be with any kind of analytical test, that machine will not deliver a perfect sample unless the material to be sampled is presented continuously and homogeneously, with the various sizes fairly uniformly distributed throughout the moving mass, and with a predetermined maximum size for the largest pieces, which must have some relative proportion to the smallest.

The difficulty of guaranteeing that any system of mixing plant shall deliver a uniform product to the mechanical sampler is, in my opinion, the most complex of any part of the sampling operation. The greatest improvement I see possible in present practice is to screen the ore to be sampled into two or more classes, 'roughs' and 'fines,' according to the size of the aggregate particles, and to sample these separately.

Probably in most cases any of the standard and well known mechanical samplers is competent to deliver a fair sample, sufficiently accurate for commercial purposes, if properly fed.

I think it important, however, to point out that in order to test mechanical samplers, the method of mixing and feeding the ore must itself be perfect, and I am sure we shall all agree that all known methods of mixing and feeding ores of widely differing sizes are liable to variation and inaccuracy, under the limitations of commercial practice.

Mr. Kiddie gives an interesting test of a 10-inch Jones sampler, and in the particular test he finds a variation of about 3 per cent. on the whole of the ore; to put it better, one side of

the sampler delivered 1.47 per cent. too little, whilst the other side delivered 1.46 per cent. too much. There is, however, nothing to show that this might not be due to the way the ore was mixed and fed, and I think in this case the machine did very fair work.

This applies also to Mr. Kiddie's proposal to make up a synthetic or artificial ore, for the purpose of testing mechanical sampling machines; unless the mixture is itself perfect, and presented continuously and uniformly, I do not see how such a test could be acceptable or conclusive.

Mr. Kiddie's investigation of the constitution of the various sizes into which an ore breaks is very interesting. I think that not only the valuable portions, but all the various constituents of an ore follow fairly well-known laws as they are broken or crushed from the solid form in which they occur in nature. The particular quality which causes any given constituent to increase or decrease in percentage in the fines, we might term its "friability." Unfortunately we have as yet no exact classification of the comparative "friability" of minerals, like the tables of the 'hardness' and the "specific gravity" of minerals. "Friability" is a complex factor dependent mainly, but not wholly, upon intrinsic hardness of the mineral, modified by its faculty of cleaving readily, and modified also by the evenness or otherwise of its fractures. The same mineral may often have two widely different co-efficients, as for instance, quartz which in its amorphous and other forms has an imperfect and uneven fracture, little or no cleavage, and great hardness, being rated in the scale of hardness as seven, the diamond being ten. Quartz also occurs in sugary, almost pulverulent forms, in which, notwithstanding the intrinsic hardness of the particles, it is so friable that it readily breaks up into fines on being handled or crushed. Many similar instances could be given to show that some minerals vary greatly in their "friability," so that an exact determination may be impossible, in addition to which the "friability" of any mineral in an ore is affected and modified by its association with other minerals or mineral aggregates.

It will be interesting to take the table giving the analysis of the particular constituents of a certain ore, in its various sizes obtained by a screening analysis. I do not know how this ore

was crushed, perhaps it had not been specially crushed at all, but taken as broken in the mine. But obviously, as 78 per cent. of it was retained on a $\frac{3}{8}$-in. screen, the crushing must have been comparatively coarse, especially as only about 3 per cent. passed through a 30-mesh screen. If the same ore had been crushed step by step still finer, after taking stage samples for assay, till say 50 per cent. of it had passed say a 20-mesh screen, the analysis of the intermediate and the final samples would have shown still more instructively how the different mineral constituents had behaved in the crushing operation. I would pause here for a moment to point out that different forms of crushing plant may produce widely different results on the grain of the mineral crushed, and hence you would not necessarily get the same results if portions of a well mixed sample of ore were separately crushed, say one by a stamp battery, one by a set of rolls, one by a ball mill of the Krupp type, and one by a disc and ring mill of the Griffin type. Rolls utilize the natural cleavage or fracture of the minerals much more than the three others mentioned, and this is why they are so greatly preferred for concentration plant, the individual particles produced having greater solidity and a much smaller proportion of fine fines. But whatever crusher be used the more friable minerals will accumulate in percentage in the fines, in the general ratio of their "friability."

Returning to the table we see that in this test ore, the gold which in the original ore was 0.22 oz. per ton remains practically uniform in the three-eighths and one-eighth oversize, drops on the 30-mesh oversize, but very rapidly increases in the 80 and 120-mesh oversize. The silver remains constant through the first three and rises rapidly and continuously through the next three. If the gold and silver had been directly associated with the sulphides, I would have expected the comparative increase of these two elements to be more nearly constant.

As Mr. Kiddie correctly points out, the test shows in the small amount of fine fines produced and particularly in the oversize, on 120-mesh the gold, silver, copper, iron and sulphur had increased in percentage in the fines, while the silica and alumina had decreased, the lime remaining practically stationary. The difference in the behaviour of the gold and the silver seems interesting, and calls for some explanation. I would also have expected to find the lime increase in the fines.

Iron pyrites, magnetite and hematite have a hardness of about 6 to 6.5; copper pyrites lies between 3 and 4 in the scale of hardness, bornite about 3, calcite about 3, and silica (quartz) about 7. If the particles moved directly according to their hardness, iron ores and quartz would more closely follow each other, the copper pyrites and the lime (if in form of calcite) would also follow each other, but the iron ores being more friable causes the crushing to act on the minerals according to their friability and not directly in relation to their hardness.

In analysing such movement it is desirable not only to ascertain the values of the elements present, as was done in this case, but it is necessary, and would have been still more instructive, to show the percentage of the minerals themselves. Thus the per cent. of the iron pyrites, the copper pyrites, the quartz, the mineral containing the lime, and all other important minerals would be shown, and a diagram could be prepared showing how each mineral travels in the process of crushing finer and finer.

Summarizing our consideration of this table, I would say that the percentage of each mineral or element will increase or decrease in the rougher or finer portions of a crushed ore almost exactly in accordance with its "friability" factor, modified by a co-efficient to be ascertained for the particular form of crushing to which the ore has been submitted.

As Mr. Kiddie has pointed out, a single analysis of the elements separated by a screen analysis of a sample of ore will not of itself give much information, and a large number of tests would have to be made on each ore, and on many different classes of ores, crushed by different forms of crushing machinery, before we could hope to build up any exact information on this subject.

Metallurgists who are constantly studying concentration work have accumulated in their laboratories a vast amount of valuable research work upon these points. It is usual in concentrating tests to apply the same method the author has applied in order to find out how minerals behave on being crushed finer, step by step, but, so far as I know, no exact classification of the minerals with their tabular co-efficients of "friability" has ever been attempted.

It often happens in these experiments where it is necessary to determine the largest size to which ore can be crushed and yet

entirely liberate from the associated gangue practically all the particles of minerals sought to be concentrated, that almost as good separation can be effected by screening as by concentration, by taking advantage of this property of the more friable minerals, to accumulate in the finer portions.

I am indeed glad to hear that Dr. J. Bonsall Porter, of McGill University, has kindly undertaken to continue these investigations and I shall look forward with the greatest interest to the publication of the results so attained. Perhaps, Dr. Porter, in his tables, will accept my suggestion and endeavour to give not only the percentage or values of the elements in the different gradings, but will also give the percentages of the minerals themselves, showing the form in which those elements are associated, as far as practicable.

For this purpose simple ores containing iron and copper pyrites, with silica and calcite, with the gold and silver associated say only with the copper pyrites, will lend themselves more readily to the earlier stages of the investigation, though it will be found, as the enquiry progresses, the scope is almost unlimited, and although different kinds of ore may furnish widely different results, all of them may I submit be referred to the same general law of "friability."

I quite agree with the author as to the great utility and as to the desirability of this further work, not only for sampling operations, but for all milling, and concentrating, and other operations, which may be affected by the form and size of mineral particles on being crushed. I think such work would best be performed under the guidance of a university like McGill, and I would strongly recommend that some special donation or encouragement should be granted by the Government for the purpose. Such a research will involve a vast amount of conscientious and painstaking work if it is thorough and productive of definite results.

Now having shown on what complex conditions the taking of an accurate sample depends, let us look for a moment at the results as attained in ordinary commerce. Here what is aimed at is not absolute exactitude and theoretical accuracy, though that is by no means too high an ideal, but we aim to get from a vast range of ores, by means of mechanical samplers operated

and controlled by trained intelligence, a commercial degree of accuracy. I think we get this now, and I do not think the interests of either buyers or sellers of ore sampled need be affected in any way by the particular make of mechanical sampler employed, or, if at all, only to a relatively insignificant extent, bearing no proportion whatever to the extent to which the human equation controls or modifies and changes the result of the operation.

I am perfectly satisfied that no practical mechanical sampling device has been, or, I might almost say, will be, evolved which can take the whole or any predetermined proportion of a parcel of ore, containing great variation in the size of the particles and in the distribution of the values, and evolve from it a pulp sample representing absolutely accurately the original parcel, without human intervention.

If a given quantity of ore can be properly mixed and presented or fed intelligently to any of the standard mechanical samplers, I consider that a commercial degree of accuracy, quite near enough for all practical purposes, should generally be attained, unless the human equation interferes with the mechanical operation, or unless some unusually complicated ore is being dealt with.

Of course, many people believe that the theory of sampling is practically the doctrine of average errors, on the principle of the schoolmaster who took the answers of a class of fifteen scholars to an arithmetical problem and wrote them on the blackboard; each of the fifteen answers was wrong, but the average of the fifteen answers proved to be exactly correct.

To some extent there must, of course, in sampling be an averaging up of variations, and the commercial result obtained in well administered works may, I think, be considered perfectly satisfactory to buyer and seller.

Some ores are, of course, much more difficult to sample than others, and there are some which cannot be sampled at all. Of the latter class I may instance the Red Hill gold quartz reefs, at Kalgoorlie, Western Australia, in which practically and often absolutely barren quartz reef carries small pockets of metallic gold of enormous value. The native silver ores of Batopilas, almost pure silver and calcite, form another instance. As a case

of a very difficult ore which required special study and investigation, I might mention the telluride of gold ores at Kalgoorlie, Western Australia.

Generally the difficulty of accurate sampling increases as the proportion of the valuable element sought decreases and is distributed irregularly in the ore. Thus, it is much more difficult to get an accurate sample by ordinary methods from a ton of quartz containing, say, $5 worth of coarse metallic gold per ton, in patches, than it would be if the same value in gold were associated with 5 to 20 per cent. of copper or iron pyrites. In the one case the element to be determined forms only an infinitesimal proportion of the total; in the latter case it is associated with minerals forming from one-fifth to one-twentieth of the whole bulk.

The difficulty of correct sampling also increases in inverse ratio to the disparity or difference (or disproportion in relative quantity) between the largest particles and the smallest particles in the parcel of ore to be sampled, as, for instance, if a parcel of ore contains comparatively few lumps from 8 to 12 inch cube mixed with a large proportion of fine fines, most of which would pass a 40-mesh screen. None the less I think the most difficult sampling problem I personally ever had to face was in connection with a custom mill in Western Australia, operating on rich telluride of gold ores, where the whole product was crushed by ball mills to pass a 40-mesh screen, that is to say, no particle in the ore was large enough to be retained on a 40-mesh screen, yet air currents and concentration both of the sizes and values set up by vibration, made this the most difficult kind of material to accurately sample.

I may point out that the test of screen analysis which Mr. Kiddie proposes to apply for testing different makes of sampling machines, is itself by no means absolute and exact. The South African Metallurgical Society has published an extensive series of investigation into this, showing that the results are greatly affected by abrasion and the influence of the human factor in causing more or less particles about the determining size of the mesh to pass through, or to be retained.

Wet screen analysis, in which the screening takes place in water, appears to be more accurate than the dry way, and is not so liable to be affected by the human element.

Finally, I wish to formally express my personal appreciation of this valuable paper. Our thanks are due to Mr. Kiddie for making the investigations and for placing the results before this Branch of our Institute.

MR. H. H. CLAUDET:—It would have been interesting if assays had been given in connection with the experiments with the Jones sampler tabulated by Mr. Kiddie (see p. 558). We would then have been able to see to what extent the variation of the respective sizes between the two sides of the sampler affected the sampling from a practical point of view.

As the author of this valuable paper points out, theoretically duplicate samples should contain the same percentage of different sized particles, and sizing tests are essential in determining the accuracy of samples; but there is bound to be some error, and the object of my remarks is to ascertain whether the variation likely to be met with when using a riffle sampler is sufficient to affect the accuracy of the sampling.

If we assume that the four products, viz.—through $\frac{1}{2}$-inch on $\frac{3}{8}$-inch, through $\frac{3}{8}$-inch on $\frac{1}{4}$-inch, through $\frac{1}{4}$-inch on 1-16-inch, and through 1-16-inch assayed respectively 0.2 oz. gold, 0.4 oz. gold, 0.6 oz. gold, and 0.8 oz. gold (being a wide range to illustrate the case), the original ore would assay 0.369 oz. gold; while the sample on side A would assay 0.367 oz. gold and that on side B, 0.370 oz. gold, which is practically a check.

MR. W. F. ROBERTSON:—The object of this paper, as I view it, was to show that in a given ore, which, I think, in this case, was a Rossland ore, the value varied with the size on the screens; namely, that certain minerals crushed more readily and made fines more easily than others, and that the value went, in that particular instance, with the fines; and Mr. Kiddie's use of the various ores of the different sizes was simply to bring out that point.

In the experiment made, the fines were the richer; but in certain other cases, the converse would be the case, namely, that the fines would be the poorer. But that does not interfere with the principle Mr. Kiddie is trying to establish, namely, the necessity for having a due, just, fair and honest proportion of fines and roughs. I think, therefore, the efficiency of the machine can be arrived at by testing whether or not it gives the true proportion

of roughs and fines; and that the synthetic mixture proposed to be made for testing these machines would be a very close criterion for testing the efficiency of any particular style of sampler.

There is another point, made by Mr. Trewartha-James, namely, the relative sizes of the fines and roughs. The mixture was coarse, with some very fine particles, showing that it was a difficult combination ore to sample. I noticed, in a paper on "Tests for Samplers," read by Dr. D. W. Brunton before the American Institute of Mining Engineers, that in any sample he spoke of he gave the proportion of the total weight of the sample to that of the largest particle contained in it. For instance, it might be a sample of 10 lb. Then he knew the weight of the largest particle. It might be one thousandth part of a pound; and the proportion would be one ten-thousandth to the sample. Then instead of 10 lb., 10 tons would be needed to be crushed so fine. I think this idea of giving the proportion of the largest particles to the total sample is a correct one and, if we can carry it out in all our experiments, it will be a great advantage in arriving at accurate tests."

MR. TREWARTHA-JAMES:—I hope you do not misunderstand me. Mr. Kiddie certainly proposes a good test to apply to any mechanical sampler. With regard to Mr. Fleet Robertson's suggestion, I think the proportion should be between the largest and the smallest particle or particles in relation to their various quantities and not necessarily between the largest particle and the whole bulk of the ore. I have been showing the difficulties we have in sampling a mixture of rough roughs and fine fines. But the most difficult case I ever saw was where the whole sample had been passed through Krupp ball mills. In this case the largest particle would pass through a 40-mesh screen, the finest say through 100 or 120-mesh screens. So that you could not apply Dr. Brunton's suggestion here.

MR. J. W. BRYANT:—In regard to the point mentioned by Mr. Robertson, that Dr. Brunton in his paper on 'Tests for Samplers,' gave the proportion of the total weight of the sample to that of the largest particle contained in it—I think this is an excellent idea, and though it is carried out in practice by the representatives of both sellers and samplers, yet it is not satisfactory to lay down such a rule as a standard. Another important

factor which should be included is the ratio between the largest piece of gangue (or gangue finely disseminated with mineral), and the largest piece of pure or almost pure mineral; for in practice covering at least a century it has been found that when an ore contains a certain percentage of lumps of pure mineral the only method of obtaining a satisfactory sample is by separating these large pieces of rich mineral and sampling them and the remainder of the sample separately.

I suggest that in future sampling practice three points be noted, namely, (1) weight of ore to be sampled, (2) ratio between total weight and largest piece, and (3) ratio between largest piece of mineral and largest piece of gangue. By recording this data there would, I think, be obtained the correct ratio to determine when it would be advisable to separate the richer portions of the ore from the bulk before sampling.

In connection with coning, I beg to make a suggestion the adoption of which would overcome the possibility of the position of the centre being altered during the formation of the cone, though it would not quite prevent the ore from grading to one side of the pile. It would, however, be a great improvement on the old method of throwing the ore direct from the shovel to the top of the cone. My suggestion is, that a funnel be supported some distance from the ground on a stand, the ore to be shoveled into this funnel and allowed to fall through it to the floor. This would, I think, be a better method than that now followed.

Mr. Kiddie:—Speaking of the small amount of fines remaining from a 30-mesh screen, I may say that these samples were obtained by gradual crushing; first by a rock crusher, and secondly through a set of rolls. I account for the small production of fines by reason of the extremely hard gangue of the ore. It was a diorite gangue with free quartz in which a great deal of the mineral matter was finely disseminated through the ore. The abrasion of the mineral disseminated in that way would not be shown proportionately as it would be were the iron sulphide, for instance, existing in a more solid condition. If we had a mixture of minerals, say pure lead sulphides and pure copper pyrites and quartz and iron ore in the pure state, putting these minerals through crushing machinery, gradually reducing the size, and then by screening, we would have the different minerals ground in proportion to

their hardness or softness. But in this case the iron and the iron pyrites and the mineral matter are mixed through with hard diorite and hard quartz gangue; and for that reason I account for the small quantity of fines in reducing it from five to three-eighths of of an inch.

Mr. J. L. Parker:—I recall an interesting discussion that took place a few years ago at a smelter with which I was associated. After passing through the various crushers, the ore was brought down to the sampling floor, where it was coned and quartered. The seller of the ore took exception to the method at this stage, on the grounds that human element was here introduced He claimed that the manager had his men so thoroughly trained that they could pour the better ore to one side or *vice versa,* if they so desired. I should like to have Mr. Kiddie's opinion as to the right way to cone a sample.

Mr. Kiddie:—I would refer Mr. Parker to a paper delivered last September by Dr. Brunton, at Spokane, Washington, exposing a dishonest system of sampling. Dr. Brunton showed that so long as the apex of the cone remained perfect and each shovelful was allowed to fall straight down the results were accurate; but he also showed that some samplers were so trained that they would gradually draw this centre from the point A to the point B. The result was that a larger proportion of the fines lay between the points A and B. Then, in cutting the sample into four equal parts, it was so arranged—by accident of course (laughter) that this part would be thrown out, making so many per cent. difference in the value of the ore. That was the first cut. The second time it was coned, the operation was continued. If there was 2 per cent. error on the first cut, it was 4 per cent. on the second. The fines were the richer in this case. So it followed that in the repeated coning of this sample the remainder was gradually getting poorer. Being a smelter manager myself, I do not think I should give these things away; but these are the facts of the case and I do not know that we ought to cover them up, when we are discussing the proper mode of sampling and the machine to be used in sampling. Above all we need a standard method of sampling, the same as we would require in any other operation. Up to the present day we have taken the sample by coning and checked it up by the riffle sample.

Mr. Trewartha-James:—A factor would be required to control that association of the minerals. Mr. Kiddie has most carefully checked the variations shown in the Jones riffle sampler. The variations between each side averaged 2.9 on the whole, i.e., only about 1½ per cent. difference between one side and the other. I wish to point out that probably in this case the assays of each side would check perfectly well within the limits required commercially, the difference being so small as to be negligible.

Mr. Robertson:—In Balbach's smelter, New York, they have endeavoured to eliminate the personal factor as much as possible in the placing of the shovelful of ore in the cone. While sampling machinery may be practical in connection with smelters, it is practically impossible anywhere outside of them; so that the old Cornish coning system must be and will be used at the smaller properties for all time to come. Balbach's sampled in this way, particularly the richer ores from South America: The ore as it reached the works in sacks was placed in a circle; the ore was dumped from the sacks where they stood, thus forming a circle of ore. The diameter of the circle depended upon the quantity of ore—it might be 12 feet, i.e., 6 feet from the centre. Three men would stand within the circle; and each man would take a shovelful from the side nearest to him, moving forward a pace as he did so, until the ore was all coned. While there might be differences in the individual factor, they would be entirely eliminated, because every man would have to go round perhaps a dozen times and each would distribute the ore in a slightly different manner.

The first idea I got of sampling was from an old Cornish miner. His method was this: The buyer quartered the sample, but the seller had the right to say which quarter should be rejected; so that, if the buyer did not quarter fairly, he was apt to get the rich part left in the sample.

Mr. Trewartha-James:—All of which goes to prove that the personal element is an important factor in present methods. I cannot see why we must have the personal element in all sampling operations. There is no reason why we cannot take a just sample and reduce and divide it mechanically, and thus get a correct sample. The only reason why this has not been done is because we have not arranged our plant so as to do it; also for

smelting purposes we wish to avoid crushing the whole of the ore finer than we can help, on account of the difficulty of smelting too great a proportion of "fines."

As a matter of fact, in certain plants—in testing works, concentrating plants, and in big gold mills—we have perfect mechanical sampling, absolutely free from the personal element. In this connection I might mention a custom mill at Kalgoorlie, in Western Australia, where we had not simply one, but three, entirely different types of mechanical samplers, ecah working against the other, and each delivering a finished sample, independent of any personal intervention. In our gold mills also, we sampled wet pulp as it came from the battery and we required that our battery sample should give not only the correct proportion of the pulp, but, as well, the proportionate quantity of water.

In smelting practice, however, we cannot reduce the ore small enough to allow of the whole being passed through mechanical samplers. The greatest improvement on present practice I can suggest would be to separately sample the "roughs" and the "fines." That is the reason why in sampling the mixtures of rough ores with "fines" we cannot attain the mechanical perfection attained in reduction works operating on a uniformly crushed product.

MINING LITERATURE.

By ALLAN GREENWELL, F.G.S., Assoc. M. Inst. C. E., M. Inst. M. E., Editor of the "*Colliery Guardian*," London, Eng.

(Annual Meeting, Toronto, 1910.)

"Mining" is defined as " the act or business of making mines or of working them," and "a mine" as a subterranean cavity or passage; especially a pit or excavation in the earth, from which metallic ores, precious stones, coal or other mineral substances are taken by digging.

Mining was one of the primitive industries and the early history of every nation bears frequent reference to it.

The Literature of Mining may be divided into Historical, Scientific, and Educational. The early references to mining are entirely historical, and the attempt to describe methods of making and working mines are of comparatively modern date. The first works of the latter description are a peculiar mixture of empiricism and superstition, for the bowels of the earth were supposed to be peopled by a race of fairy miners known variously as gnomes, goblins, trolls, etc., and magic was a common belief.

Progress in the preparation for use of the mineral after it had been dug, also lagged under the influence of the superstition of the times, and alchemy usurped the science of chemistry.

It was not until engineering came to the aid of mining and by the introduction of steam engines and machinery and the knowledge of mechanical structure, enormously extended the scope of the industry; and chemistry and geology, supplied the knowledge of the character and relationship of the materials dealt with, that the scientific literature of the subject may be said to have commenced. The first practical books upon mining began to appear in the early part of the last century, but as books were costly and

comparatively difficult of access in those days, their influence was restricted.

In addition to this the scientific world kept its own literature very much to itself, lest its labour should be degraded by being put to practical use. As recently as 1903 the Savilian Professor of Astronomy at Oxford deliberately accused those who apply science to useful ends, of the possession of vulgarity of mind.

Towards the middle of the last century, however, a number of influences came into play. The application of science to industry began to grow with rapidity, and its various branches became departmentalised. The advantages of theoretical knowledge in practice gradually came to be recognised, and resulted in the spread of technical education. Books became cheaper, a technical press came into existence, and the multiplication of libraries rendered these sources of information more generally available. Mining Engineering grew into a recognised profession, and its members banded themselves into Associations and Societies and communicated the results of their experience and research to their fellow members in the form of papers and in the course of discussions.

Innumerable works on mining were written, the field covered constantly becoming larger.

Some idea of the variety of subjects comprised by a general knowledge of the Science and Art of Mining may be gathered by reading the Synopsis of Contents of the article on the subject in the 9th edition of the Encyclopedia Britannica, published 1875-89. Since then, however, many new subjects have been added as a result of the advancement of science; a knowledge of all of which the competent mining engineer is presumed to possess.

The advancement of Technical Education and the recognition of the necessity for training Mining Engineers for their profession has given birth to the Text Book, the true function of which is to give the Student a bird's-eye view of the field of knowledge which he is expected to cover, leaving each particular subject to be subsequently more exhaustively studied by means of special Treatises. This has drawn a distinct line of demarcation between the old-fashioned General Treatise on Mining and the modern Students Text Book.

Attempts are, however, made now and again to compile a cumbersome and unwieldy work purporting to cover the ground which has become almost limitless owing to modern research. These works remind one of a sort of literary Frankenstein built up of limbs hacked from a number of separate organisms, which are slung together, and to which the enterprising publisher imparts a flickering breath of life. They are deplorable productions, and the only consolation is that they occasionally turn and rend their authors.

The Encyclopædia Article is a legacy of the General Treatise, and claims to dispose of a vast subject within the limits of a short essay. The practical use of these articles is difficult to discover, beyond supplying material for platform oratory and the Daily Press. A story is told of a lady who asked a famous violinist to give her a few lessons. On learning that the lady possessed no knowledge whatever of the instrument he delicately pointed out to her that in order to attain any degree of proficiency with the violin a student should commence very young and work at it assiduously for many years. The lady, however, assured him that she did not desire to "learn" the violin, but only wanted to know sufficient to be able to "teach" it! Unfortunately the Professor's reply is not recorded, but perhaps he recommended the lady to consult the article on the Violin in the Encyclopædia.

At this stage of development Mining Literature may be said to consist chiefly of:

1. Text Books.
2. Special Treatises.
3. Transactions of Associations.
4. Technical Press.

Of Text Books on Mining there is no end, and many of them are excellent. The main features of them all are necessarily the same, the differences being rather in the method of treatment. The simplest are usually the best and their comparative utility depends largely upon the clearness and intelligibility of the diagrams and illustrations. Text Books are frequently written by Professors, and are specially adapted to the requirements of the students attending their lectures. Before sitting for an examination it is advisable for a candidate to inquire if any of the examiners have written Text Books; if so the books should be immediately procured and studied.

Treatises upon special subjects are now becoming very numerous, but their value is very uneven. The cost of publication by an author on his own account of even a small technical work is usually prohibitive as the outlay comes at the commencement, and as the class of readers is small compared with that of works of fiction and popular literature, the return is slow. The would-be author has, therefore, to find a publisher willing to take the risk of producing the work at his own expense. The publisher naturally considers the proposition solely from a business point of view, with an eye to a quick turnover, and gives a preference to an author who has already acquired a reputation rather than to the intrinsic merit of the work. Consequently a new author finds a difficulty in getting his book published, while the works of others multiply and frequently show a tendency towards degeneration. As a result many able treatises first see the light of day in the transactions of associations, the author sacrificing pecuniary profit but securing professional reputation. Apart from the obvious gain to the fortunate association, the author derives no inconsiderable benefit by at once reaching an appreciative and concentrated public.

The wide success of a Special Treatise published in book-form depends, to an extent little realised, upon extraneous circumstances. It should be printed in good large strong type (not like spider's web), well-spaced with dead black ink on good paper. The diagram should be placed in such a position as to be easily referred to when reading their description, and should be clear and specially drawn for the work which they are intended to illustrate. Diagrams are usually printed from process blocks made by reduction from drawings, and this reduction should be borne in mind when making the drawings, especially as regards the lettering. Many diagrams are very difficult to understand on this account as the lettering becomes miscroscopic. The book should have a good index, the making of which is an art in itself. Preferably the book should be brought out by a publisher of similar works; otherwise, it is apt never to reach the particular section of the public for which it is intended.

The selection of the title-in-chief is most important. The branches of research in mining are so numerous, and are approached from so many different points of view, that the title of a book which gives the subject without an indication as to its scope often

causes much disappointment and needless enquiry. For instance there is a book entitled on the cover "Mines and Mineral," the subject of which is the *Law* of Mines, Quarries and Minerals in *Scotland*.

It is necessary to remember that the same word does not always convey the same impression to different persons. For instance we have it on the authority of the poet Wordsworth that to Peter Bell;

> "A primrose by a river's brim
> A yellow primrose was to him,
> And it was nothing more".

While to Professor Huxley it was—

> "A dicotyledonous exogen with a central placentation and a mono-petallous corolla."

Perhaps the difference is not really very great, but still it might cause confusion.

A large proportion of books are bought or referred to in consequence of their chief-titles, and inaccuracy in these causes inconceivable loss of time and annoyance. The story of the second-hand bookseller who catalogued consecutively two books as Mill on Logic: Ditto. on the Floss, is by no means an isolated one, and probably there are few mining men who have not been led astray in a similar manner by imperfections in the titles of books.

The most fruitful source of Mining Literature is unquestionably the Transactions of Mining Associations which are growing steadily in number and usefulness.

They normally consist of the record of actual work written by practical men for the consideration of practical men, and are thus honest and straight-to-the point. The value of these papers is often enormously enhanced by the discussions following them. The only drawback is that the transactions of any particular association are easily accessible only to its members. There is an increasing tendency to file transactions of some of the important associations in the large reference libraries, and in each other's libraries, but these facilities are very inadequate. The difficulty has to some extent been met in England by the federation of the several mining institutes and the publication jointly of one set of proceedings. Membership of any individual mining institute carries with it the advantage of receiving the selected transactions of all the other institutes as well as those of his own.

There are, however, many extremely valuable papers which are read before less prominent societies, printed in their transactions and practically buried.

Excellent work is being done by the "Engineering Index" and other bibliographic works by providing a reference to the titles of articles appearing in a large number of publications. This is a work which should be placed upon a much wider basis and is even of international importance. Perhaps the time may come when this matter will receive the attention it deserves and we shall have a World's Literary Reference Bureau.

Finally we come to the section of the Technical Press which deals with Mining. The Technical Press comprises the financial mining press and the mining press proper.

The financial press is more nearly associated with the speculative side of the industry and its literature is largely derived from Mining Prospectuses and the Reports of Mining Experts. Paradoxically it is at once the shady and the light side of Mining Literature, for it connotes the atmosphere of libel suits and commercial failures, and the fields of flowery fiction of which Sindbad's Report on the Valley of Diamonds Claim, as recorded in the Arabian Nights was merely a foretaste.

The Mining Press proper is by nature historical, scientific and, occasionally, educational, and its claim to esteem depends in each case upon the manner in which the journal is conducted. At its best it is historically a continuous and faithful representation of events, properties and men, but its records lack in perspective.

In mining matters, par excellence, true estimates can only be formed at a distance.

The scientific element of the Mining Press is substantially recruited by means of authors who failing to secure publishers for their works, are unwilling to part with them gratuitously to the Transactions of Mining Associations. An inherent misfortune of the technical journal is the well known fact that it cannot exist upon the income derived from subscriptions, but is almost entirely dependent upon advertisements. Advertising firms are well aware of this, and play the newspaper proprietors very hard by making their financial support dependent upon the insertion of articles exploiting their wares, which while purporting to be independent are in reality highly coloured *ex parte* statements.

In adopting this policy manufacturers defeat their own ends, for they neglect the fact that the value of a journal as an advertising medium depends upon the extent to which it is read by those who are interested in the purchase of machinery and plant.

An intelligent mine manager has usually little difficulty in detecting an attempt to "force a card" upon him, and he immediately becomes suspicious.

A trade journal should have the moral courage to adopt and adhere to an independent line of action by including in its columns only unbiassed reports made by competent engineers who have obtained their information from sound personal investigation. Such a course cannot fail ultimately to secure a degree of respect both from its readers and from the manufacturers which will redound to their mutual advantage.

"Show me a people's Literature and I will show you its History!" might have been equally said of an Industry, and Mining Literature fairly reflects the vicissitudes of fortune in this particular instance.

Considering all its opportunities and temptations without being fastidious, it may be claimed for mining literature, as well as for the industry which it represents, that it can show a fairly clear bill of health and that its development is progressing favourably.

DISCUSSION.

MR. MURRAY:—While listening to the reading of Mr. Greenwell's excellent paper, a contrast struck me. Some years ago I picked up an old Freiburg mineralogy. In turning over the pages of this I noticed an appendix in which were given the specific gravities of various substances, and among these substances was "Warm Asses' milk and Miner's urine." The inclusion of these things in a book devoted to such a subject as mineralogy throws a charming side-light upon the educational methods of the day. We would hardly expect to find corresponding digressions in the valuable pages of Dana. (Laughter.)

MR. HOBART:—Some years ago I had occasion to consult a German treatise and I came across a description of some metallurgical process that had been in use at an Austrian mine. After I had spent the better part of two days working it out in rather crabbed German, I found at the end a statement that this process had not been used since the middle of the Seventeenth century. (Laughter.)

There are other mining treatises, some written by professors—most of them I am afraid by professors—that are not much more useful or practical than that German treatise to which I have just referred. I do not mean to say that all professors' treatises are impracticable; but I do mean to say that often they are apt to have a tendency in that direction. It seems to me that a book on mining should be written by a practical miner, who knows what he knows by practical experience. (Hear, hear.)

MR. MURRAY:—Possibly Mr. Hobart overlooked the valuable work done by compilers—that monumental work on ore dressing by Professor Richards, for example. I am not aware whether Prof. Richards has spent very much of his life in actual mining; but certainly his books are standard works.

MR. HOBART:—Well, I agree with what Mr. Murray has just said. I don't mean to say that all professors write books of the kind to which I have just referred, nor do I refer to the work of compilers. Any work on mining must necessarily be largely a work of compilation; but I do think that the compiler should have practical knowledge,—at all events sufficient practical knowledge to enable him to know what he is speaking about, and that he should not take up the subject simply for its historical aspect, or from a too general scientific point of view.

THE PRESIDENT:—This paper has been written by an editor and it has been discussed by two editors. Now, I think we should have some discussion on the paper from men who write treatises.

MAJOR MAGEE:—I generally try to read whatever is recommended in the scientific papers. If Mr. Murray called my attention to a book that he considers very useful, I would possibly read it; and I think that is the way books generally come to be read, because everybody cannot read all the books published on mining, and we expect the scientific journals to recommend us to the best and most useful.

In respect of Mr. Hobart's criticism of books written by professors, I am inclined to believe that professors should be good authors, since they have greater facilities for compiling and getting together information than most people, for they have both leisure and libraries.

MR. HOBART:—There are "professors" and "professors." By the term "professor" I mean it to apply to a man who is a professor and nothing more; that is to say a book man. Now, the best professors that we have—and I am happy to say there are quite a number of them,—have had practical experience before they became professors, and consequently they are just the type of men who know how to teach. They are not merely professors in the ordinary sense of the word, but they are also miners, and they should not be confused with the man who has had no practical experience, but who is a book man purely and simply, and I think we have fewer of this latter class in this country than in any other. In Germany I understand they have a great many men "book men."

SOME NOTES ON THE HISTORY AND RECENT DEVELOPMENT OF THE CANADIAN MINING INSTITUTE.*

By H. Mortimer-Lamb, Secretary Canadian Mining Institute.

(Cobalt Branch Meeting, Nov. 25th, 1909.)

Although the Canadian Mining Institute is still a relatively young organization, it may be safely assumed that a very considerable proportion of its present membership is uninformed concerning the early history of the society, the causes that led to and resulted in its organization, or of the useful services it has rendered the mining industry since its inception. An explanation of this condition of affairs is, however, readily found when it is considered that mining engineering, unlike most other professions, is a sort of will-o'-the-wisp to those who adopt it. It is rare for a man following this calling to remain for any length of time in any one place or country. If he succeeds in establishing a reputation in a particular locality, there immediately arises a demand for his services, with the proffer of greater inducements, elsewhere. If, on the other hand, his management of a mine in one camp is inefficient, he necessarily drifts on with the stream. Thus, of the original membership of the Institute few now remain on the list, the ranks having been recruited year by year, and especially during the past two years, by new men—men either of a younger generation fresh from the mining schools, or by engineers or mine managers or superintendents representing outside capital, recently attracted to Canada.

The inception of the Institute may, properly, perhaps, be ascribed as dating from the year 1890, when a very pernicious and unjust measure was passed by the Quebec Legislature, imposing a royalty of 3 per cent. of the gross value of the product upon mines already alienated from the Crown by actual sale, without any reser-

*Abstract.

vation of the right to levy such royalty. The Act also contained other provisions similarly retroactive in effect and unfair in character. It was realized that if this Act were allowed to become operative, it would not only be a heavy blow to established industries, but would also seriously check new enterprises. At this time the only periodical devoted exclusively to Canadian mining interest was the "*Review*", published at Ottawa, and edited by Mr. B. T. A. Bell, a young Scotsman possessed of extraordinary energy and force of character. At his initiative a meeting of the mine operators of the Province of Quebec was convened and held in the Windsor Hotel, Montreal, on January 23rd, 1891, primarily to combine in opposition to this measure; but during the evening a resolution was formally adopted whereby the Quebec General Mining Association came into existence.

Following this example, a year later, March, 1892, the organization of the Mining Society of Nova Scotia* was effected as the result of a circular issued by Messrs. J. E. Hardman, R. G. Leckie, Chas. Fergie and others to the mining men of the province, in which their co-operation and interest were invited in the formation of a United Miners' Association, the object of which was to promote generally the welfare of the mining industries. The society immediately justified its existence by its success in inducing the Nova Scotian Government to modify, and in some instances to amend entirely, certain ill-advised clauses in the province's enactments relating to mines and mining leases, which were shown to be inimical to industrial interests.

Ontario was the last of the three Eastern Canadian mining provinces to organize; but here again, thanks to Mr. Bell's exertions this was accomplished in April, 1894, when a meeting was held for the purpose at the Rossin House, Toronto. Of those among the first to sign the roll of membership it is interesting to note the names of Prof. W. G. Miller, who for the past two years has so worthily filled the office of president of this Institute; Mr. R. W. Leonard, Mr. T. W. Gibson, Dr. Goodwin, Dr. Nichol,

*The Gold Miners' Association of Nova Scotia was organized a month or two prior to the organization of the Quebec Mining Association. Its *raison d'être*, however, was primarily to prevent, by the combined efforts of mine-operators, "high-grading" or the stealing of gold by mine employees. Its scope was, therefore, somewhat limited and consequently in considering the genesis of The Canadian Mining Institute, the influences of this organization thereon has been disregarded, as having no direct bearing.

Dr. Coleman, Mr. J. M. Clark, Mr. J. T. Laidlaw, and others still prominently identified with the industry. The existence of the Ontario organization as an independent body was, however, brief. The society, in fact, was never incorporated, since when this was proposed the question of the federation of the three associations had already been mooted, and the men of Ontario fell readily in with the project. But while the desirability of the step was generally agreed upon at a united meeting of the three societies at Cape Breton in July, 1894, federation was not finally consummated until January 10, 1896.

The birth place of the Federated Canadian Mining Institute was Montreal. Its first president was Major R. G. Leckie. The scheme, which had as its main objects, economy in publication, consideration of matters affecting or relating to the mining industries of the Dominion within the jurisdiction of the organization, and the holding of a united meeting annually, aiming in no way to interfere with the autonomy of the respective societies, proved only moderately effective; and when in 1898 some accessions in membership were obtained form British Columbia, it was decided to reorganize on somewhat broader lines by the creation of a society essentially national in its aims, character and scope, and governed by a central administration. Thus, at the close of the annual session of 1898, the Federated Canadian Mining Institute was dissolved, and the Canadian Mining Institute (incorporated by Act of Parliament), founded in its stead. The Institute's first president was Mr. John E. Hardman, while Mr. Bell continued to act as secretary until the time of his death in 1904. When originally organized, the membership of the Institute was but sixty-three; but its success was assured from the start, and before the close of the year this number had increased to one hundred and ninety. To-day it is between eight and nine hundred.

The popularity of the Institute and its growth during the past eleven years may, mainly, be attributed to the fortunate selection of able and public spirited men to direct its affairs as members of the governing body or council; for the Institute could not have influenced public opinion, secured recognition from governments, or otherwise played as it had a momentous part in the amelioration of conditions, had the men who administered its affairs and policies been anything else but zealous,

able and disinterested. It is, meanwhile, a matter of record that one of the Institute's presidents, at the time resident in a distant part of the country, never once failed in his attendance at a Council meeting during his two years' term of office, although to perform this duty he was obliged on each occasion to undertake a special journey of over a thousand miles. Again to attend an annual meeting the president elect in 1907 travelled over six thousand miles; while last year the president of the Institute devoted no less than seven weeks of his time to the performance of the far from nominal duties falling to the lot of the Institute's chief official representative on the occasion of the ocean to ocean excursions; which represented ten thousand miles of continuous travel. These are merely instances. It may be added that there are very few men who having been elected to serve on the council have neglected to realize their responsibilities; and to their devotedness, interest, loyalty and singleness of purpose the society is very deeply indebted.

As to the actual accomplishments of the Institute during the period under review, these of course, include those advantages common to all successful societies of a like nature; such advantages, for example—social and educational—as are derivable from professional intercourse, the interchange of views and ideas between men following the same calling; and by the publication and dissemination of valuable information and records. But probably no mining society in the world has exerted itself to an equal degree or to better purpose in safeguarding the interests of its members, or rather of the industries they represent, against the passage of oppressive or ill-advised legislation, or has done more to influence the introduction of remedial measures where these were necessitous. Merely to indicate the scope of the Institute's activities in these directions, allusion need but be made to one or two instances of its successful opposition to the passage or operation of ill-considered legislation, such, for example, as the Order-in-Council of the Ontario Government in 1899, recommending the imposition of an export duty on copper-nickel ores and mattes—the effect of which, had it been put in practice, would undoubtedly have been to paralyze the nickel industry in Canada; and the proposed "Act to amend the Mines Act" of Ontario, 1900, which, as originally framed, and actually passed a

first reading, imposed absolutely ruinous and prohibitive taxes on the mining industry of the province. Again, in more recent times the advice of the Institute has been repeatedly sought by both the Dominion and Provincial Governments in respect of proposed mining legislation; while if the society had done nothing else, its claims to consideration would have been more than upheld by the successful result of its endeavours whereby a Federal Department of Mines has been established under the direct administration of a responsible Minister. The recent repeal of the Quebec Mining Law, and the enactment of a new set of regulations decidedly more conducive to the encouragement of legitimate prospecting and industry, is also directly traceable to the Institute's representations.

Other testimony might readily be adduced in evidence of the Institute's activity and useful services in the past, but doubtless sufficient has now been mentioned to fully serve all present purposes.

It may now, meanwhile, be permissible to refer more specifically to the objects of the Institute, to the ideas of the promoters who formulated them, and to compare conditions existing when these ideas were adopted with conditions to-day, in the hope thereby of provoking discussion on some of the questions involved. Briefly, then, these objects as set out in the Institute's charter, comprise the promotion of the arts and sciences connected with the economical production of valuable minerals and metals; the distribution of information; the establishment of a central reference library and headquarters; concerted action upon matters affecting the mining and metallurgical industries of Canada, and lastly, the encouragement and promotion of these industries by all lawful and honourable means. These objects, it will be noted, cover a very wide field, and are very much more comprehensive, than that, for example, of the Institution of Mining and Metallurgy, which, as a strictly technical society, confines its aims to the general advancement of mining and metallurgical science. The charter of the Canadian Mining Institute, moreover, differs from the constitution of the Institution of Mining and Metallurgy in that the former contains no clause relative to the qualifications required of persons seeking enrolment as members, the matter being regulated merely by by-law, which is subject

to amendment at any annual meeting; whereas in the case of the latter these requirements are very explicitly defined, and are not amenable to change. The records of the Institute, however, show that its founders very carefully considered the issue of the desirability, or otherwise, of organization on strict lines of technical or professional qualifications; and that they then concluded that the time was not opportune to attempt to found a society composed exclusively of professional men; and that, furthermore, if all conditions were favourable to the promotion of such a project, greater ends would be served by organizing on broader lines, and by launching an organization that would embrace within its scope of activities not only the promotion of the arts and sciences of mining, but that of the industry of mining also. Hence, this was the idea that found expression in the charter, and the by-law regulating the matter of the eligibility of candidates for enrolment gave the Council practically without limitation or restriction discretionary powers as to whom they might admit to membership. Every system, however, is liable to abuse, and there can be no doubt that during the first few years of the Institute's existence, in the natural desire to increase its membership, less care than might have been was exercised in scrutinizing the status of certain candidates, with the result that several were admitted whose admission reflected no credit on the organization. No change in this general policy was made until some three years ago, when, at the annual meeting in Toronto, a new by-law was adopted establishing a second grade or class of membership. This new by-law, while not limiting the Council's discretionary powers, was at least a suggestion to that body to thereafter discriminate between technically and non-technically qualified persons applying for enrolment, by classifying the latter as associate members. As to the advantage of this change opinion is still somewhat divided, although generally, it is believed to be favourable. The by-law has meanwhile been in force for nearly three years. During that time the membership has very nearly doubled. In 1907 there were elected 161 members and 34 associate members; in 1908, 87 members and 62 associate members, and in 1909 to date, 49 members and 52 associate members.

It will be noted that the distinction between a member and an associate member is little more than nominal, the associate

having all the privileges of membership, with the exception only that he is debarred from holding office. The attempt to classify the membership may be said, then, to have a sentimental basis rather than anything else, although its ultimate aim may be eminently practical. Thus, even full membership in the Canadian Mining Institute does not at the present time imply professional proficiency or even professional experience. A graduate fresh from college is as eligible for full membership as is a mining engineer of international repute. The Institute merely draws a line, and a not particularly distinctive line, between those professionally engaged and those commercially engaged in the mining industry. Nevertheless, even this somewhat meaningless discrimination has, in the writer's belief, served to popularize the Institute with the class of men whose interest and support is of chief value to the society. Although, as has been stated, the Institute represents an industry and not a profession, it can scarcely be disputed that the esteem in which the organization is held and the influence it exerts, is mainly attributable to the fact that its membership is preponderantly professional in character. Again, the technically trained engineer or practical mining man is necessarily in a position to render greater service to a society, one of whose chief objects is the publication of technical information, than another whose qualifications to express himself authoritatively on this subject are entirely limited.

In conclusion, a word may be said on the Institute's recent policy of establishing branches throughout the country. The idea is not a novel one, even in the Institute, it having been first suggested and partly carried into effect by Mr. Bell in 1902. It was also enthusiastically advocated by Mr.Coste during his term of office in 1903 and 1904. The successful operation of the branch system, however, is of comparatively recent date, and takes into account the organization of the Toronto, Cobalt, Montreal and Western branches. Of these, the Cobalt and Western branches are naturally the most important, and have served the most useful purpose; in fact, a large increase in membership during the past two years is chiefly due to the activities of these two branches, and of their executive officers, to whom the Institute is under considerable obligation. Until quite lately there has been much opposition in certain quarters to the establishment of branches, and even now some very able gentlemen hold the view that the expedient is

a mistaken and dangerous one. Their ground for this belief is that branches foster and encourage localisms and sectional feeling; that they threaten to become a drain on the finances of the Institute, and, in brief, are likely to be a source of weakness rather than of strength. These objections contain, no doubt, at least a germ of truth, and it is well that they should be raised in order that any possible contingencies may be combatted before they actually arise. The Institute's chief claim to recognition, its power for good, is on the score of nationalism. As a national organization it is in a position to accomplish what would be otherwise impossible. This should be recognized by every member, whether he belongs or not to a branch organization. Branches were originally established to meet conditions peculiar to this country. The centres of mining activity in Canada are widely scattered, and spread across a continent. It was realized that a great majority of members could not, by reason of these great distances, attend meetings; that it was difficult to keep in touch with them from headquarters, and that consequently they were apt to become indifferent to the Institute, or lose interest in it altogether. Apparently the only feasible way to overcome these difficulties was to create enthusiasm by local organizations, and thus provide machinery whereby men residing in the same locality might be enabled to meet as members of the Institute in common cause. It was in no wise intended that these local branches should become more than this. So far, the plan has proved most effective.

MINING ENGINEERS AND MINING INSTITUTES.

By J. D. Kendall, London, England.

On more than one occasion I have tried to induce engineers to discuss this subject with the view of arriving at some general understanding and resolution as to the means necessary to place mining engineers in a position before the law, similar to that occupied by members of other professions.

Spencer has truly said: "It is only by varied iteration that alien conceptions can be forced on reluctant minds." I therefore return to the subject once more, knowing however that the conceptions are alien to some only, although the reluctance to deal with them seems to be almost general. Why it should be so I cannot understand. Why should men, who know their business and are prepared to do it honestly, allow a large part of it to be taken from them by the impostors who gather in all new mining districts and sometimes in old ones and are always ready to barter a favourable opinion for an approved monetary consideration, and who, in so doing, bring disgrace upon a profession which, when properly practised, is in the highest degree honourable? This, of course, I know is only an egoistic view, but from the altruistic standpoint the prospect is equally satisfactory. The rooting out of impostors must, at all times, make for the benefit of mining investors and consequently for the benefit of a mining country generally. To the persons who employ these impostors there would, doubtless, be serious loss, or rather the sources of their illegitimate revenues would disappear; but that would be a matter for congratulation rather than regret.

The question then arises, how are these impostors to be weeded out? In my opinion it can only be done in one way. In every mining country an institute should be established by par-

liamentary enactment and every person practising as a mining engineer in any country should after the expiration of his pupilage be compelled, under serious penalties, to become a member of the institute of that country and gain admission to it by examination only, except in the case of men eminent in their profession, in whose favour, for the first six months or so after the establishment of an institute, the examining boards might dispense with the usual conditions of entry. Every candidate for admission should have to produce to the examiners, at least two written testimonials as to character from persons who have known him intimately for at least four years. After the first six months of an institute's existence these testimonials should be from members of the institute. Any person practising before admission to the institute should be liable to serious penalties enforceable by law.

Membership of the institute should be graded according to experience and other qualifications, and the different grades should be indicated in such a manner that the public cannot possibly be misled as they are at present. I recollect the case of a man, who some years ago, in recommending a very "wild-cat" to the public wrote the initials E.M. after his name. Later he was obliged to appear in a law court to support his recommendation and was there asked if he was an engineer of mines. He said "No, the letters in my case simply mean expert miner." A similar misleading use of the initials employed by a statutory-formed institute to indicate membership should be made punishable by law.

The requirements of the examining board should be ethical as well as intellectual. I am convinced that our whole system of education is wanting in this connection. The ethical side of a man's mind is not cultivated to anything like the extent it should be. A knowledge of right conduct no more grows with us than a knowledge of geology. Besides the general rules of conduct, which ought to be taught with the three R's, there are rules of special application to the different walks of life. Some of these, so far as they affect the mining engineer, were referred to in a previous communication. They should be made rules of the suggested institute and their infraction should be made punishable by removal from its rolls. They should, moreover, form part of an engineer's education and not be left for him to find out in later years after he has unwittingly done some of the mischief to which

their non-observance will surely lead. Engineers are frequently offered contingent fees which, I need hardly say, should always be refused unless the contingency be legitimate profit to their employers. Young engineers are often greatly puzzled to know what to do in the circumstances, such matters never having been dealt with in their training, as they ought to have been. I remember a case in which a well-known person went into a young engineer's office for the purpose of obtaining a report on a property he intended placing before a company of which he was director. He said "I am not sure that I can sell the property, so I want to make an arrangement with you something like this—if I don't sell the property I will give you $50 for your report; if I do sell it, I will give you $1,500." The young engineer very properly declined this offer, saying "my charge will be $250 whether you sell or not." Think of the inducement there is in such an offer to produce a favourable report, and the necessity of pointing out to students the true inwardness of all such offers must be at once conceded.

I have purposely refrained from loading this communication with the many illustrations which might be adduced to show the necessity for the suggested changes, because there must occur to the mind of every engineer of experience many such illustrations. Can anything conclusive be urged against the proposed changes? If not, I hope this Institute will take the lead in what I and others, with whom I have spoken, consider to be a much needed reform and establish itself on the lines indicated or on some similar lines which will give its members and the mining public that protection from the operations of the "yellow-legger" and the unprincipled promoter they so much need. Much can be done by such an institute in the way of exposing and thereby putting a stop to the crooked methods of the latter, that individuals, however courageous, could not afford to do.

In a country where a man cannot practice as surveyor or assayer without a certificate of competency it seems very much of an inconsistency that the far more important work of the mining engineer can be practised by anyone. Assaying and surveying are merely items in a mining engineer's equipment, so that we are led by the *status quo*, to the anomalous inference that a part is more important than the whole.

It is not for a moment thought that any or all of the suggested changes would place engineers on one plane of efficiency. Differences must always exist so long as variation and environment are factors in organic evolution. But with the suggested reforms we should have engineers and *engineers*. Now we have engineers and fakirs.

The institute advocated, which might be called the National Institute, need not in any way interfere with the local or provincial institutes which are so necessary for the reading and discussion of papers. But if the publication of the papers were undertaken by the National Institute the reduced cost would, to some extent if not entirely, offset the diminished revenue, for the number of members would certainly be reduced under the proposed scheme. But I think engineers would readily agree to an increased subscription in consideration of the protection they would obtain and their improved legal position generally.

THE CLASSIFICATION OF NICOLA VALLEY COALS.

By S. J. Castleman.

(Western Branch Meeting, Vancouver, Feb., 1910.)

Nicola Valley is in the Yale district of British Columbia, through which the Nicola river flows westward, joining the Thompson river at Spence's Bridge station, on the main line of the Canadian Pacific Railway, 178 miles east of Vancouver. The principal coal mines of the valley are operated by the Nicola Valley Coal and Coke Company and are situated at the junction of the Coldwater and Nicola rivers, 40 miles southeast of Spence's bridge.

Considerable misapprehension exists as to the proper classification of the coals of Nicola valley, especially in the eastern provinces of Canada, and it is for the information of mining engineers not familiar with the district that the data herewith submitted are offered, inasmuch as statements are made from time to time, through the press of the country, in effect that Nicola Valley coal is lignite and not bituminous, as claimed by those who are interested in the development of that district.

In 1902 Nicola Valley coal was analysed by Thomas Price & Sons, consulting chemists, of San Francisco, California. The average of four samples obtained by this firm was:

Moisture	Vol. Comb. Matter	Fixed Carbon	Ash	Sulphur
2.66	36.72	53.45	7.16	0.66

Per cent. of coke, 60.61; nature of coke, firm and coherent.

This coal was taken from outcrops on what is now the property of the Nicola Valley Coal and Coke Company. From the report

accompanying the analyses I quote as follows: "The showing should certainly be very encouraging to you, exhibiting as it does good qualities of coal with very superior coking qualities."

In the same year samples of this coal were sent to Dr. Milton Hersey, city and provincial analyst, in Montreal, and an average of four determinations made by him was:

Moisture.	Vol. Comb. Matter.	Fixed Carbon.	Ash.	Sulphur.
2.67	37.10	52.27	7.95	0.77

Absolute heating value, in terms of British thermal units, 12,370. Per cent. of coke, 60.19. Nature of coke, *hard, firm and of excellent quality.*

Even as far back as 1872–1873 the good coking quality of the Nicola Valley coals was known to Canadian geologists, as instanced in a report made by B. J. Harrington, B.A., Ph. D., addressed to Professor Alfred R. C. Selwyn, F.R.S., then director of the Geological Survey of Canada. In this report Dr. Harrington submitted an analysis made by Dr. Hunt, which by slow coking process gave:

Vol. Comb. Matter.	Fixed Carbon.	Ash.
21.51	74.58	3.91

yielding a *firm, dense coke.*

In February, 1907, samples were taken from the workings in the Jewel seam by Mr. Thomas Kiddie and submitted to Mr. Herbert Carmichael, government analyst for British Columbia, for analysis. Mr. Carmichael reported the following result:—

Moisture at 100c.	4	per cent.
Moisture at 115c.	0	"
Volatile Combustible Matter	33	"
Fixed Carbon	58.50	"
Ash	8.50	"
Sulphur	0.20	"
British Thermal Units	13,268	

Pounds of water evaporated by one pound of coal, 13.73.
Coking properties, good.
The coal is not a lignite.

In 1909 Professor Milnor Roberts, Dean of the School of Mining, University of Washington, U.S.A., visited Nicola Valley, and afterwards wrote an informative paper on the coal field

in this district. This was read at the Spokane meeting of the American Institute of Mining Engineers, held in Spokane, Washington, in September, 1909. During that visit Professor Roberts collected numerous samples from various properties in course of development, comprising the several properties of the following companies:—

Nicola Valley Coal & Coke Company, Nos. 1, 2 and 5 Mines;
J. Graham's—upper and lower seams; and
Diamond Vale No. 3 slope.

These samples were taken by Professor Roberts from such points as may be said to fairly represent the entire coal field of the Nicola Valley, and were analyzed by Prof. C. R. Corey, of the University of Washington, Seattle. An average of these samplings was as follows:—

Moisture.	Vol. Comb. Matter.	Fixed Carbon.	Ash.	Sulphur.
4.33	38.83	50.84	5.94	0.64

All coking coal.

In 1909 a request was made to the Nicola Valley Coal & Coke Company, by the representative of Messrs. Burt, Boulton & Haywood, Limited, of London, England, for a 10-ton lot of coal, which was accordingly shipped to Liverpool and there coked in the Simplex by-product coking plant at Claycross. This firm reported that they found the coke produced from the Nicola Valley coal equal to the best English or Welsh coke.

They further stated that this coal was treated in the same manner as the usual run of coal at the ovens, the ovens being arranged for handling a coal which is very difficult to coke, and that a lighter and more porous coke could, of course, be made if desired.

From the above testimony as to the analyses and coking quality of the Nicola coal, it will be apparent to members that these coals should be classified as bituminous, and it is hoped the independent data here submitted will be found sufficient to substantiate this contention.

STUDENTS' PAPERS

THE USE OF COBALT OXIDE FOR MAKING PIGMENTS.*

By J. J. MCEACHERN, School of Mining, Kingston.

The purpose of this paper is to give the results of some experiments, which were made in an endeavour to test the possibilities of extending the use of cobalt oxide. In view of the greatly increased production of cobalt, since the discovery of the Ontario silver-cobalt deposits, it seems possible that cobalt may be used more extensively in the arts from which it has been entirely or partially excluded by its high price and limited production, rather than by technical objections.

Cobalt has been used successfully in the manufacture of permanent blue and green pigments, but the commercial use of such pigments has been very limited, probably because of the cost of the cobalt necessary to their manufacture. At the present time they are practically unknown to painters, although some shades of a pigment, known as ultramarine blue, are sometimes sold under the name of cobalt blue, though containing absolutely no cobalt.

The production of cobalt from the mines of the Temiskaming district very greatly exceeds the consumption of the finished oxide. An attempt has been made to compare the present and past consumption of cobalt with the possible production from this source. In addition, a general effort has been made to show, by statistics and comparisons, that there is a possibility for the development of a pigment industry, which would be based on a comparatively cheap supply of cobalt oxide.

EARLY HISTORY OF COBALT MINING IN SAXONY.

The early history of cobalt in Saxony has been described in a very interesting paper by Professor Mickle, in the Report of

*Awarded a Prize in "Students' Competition, 1910."

the Bureau of Mines of Ontario, 1905, who states that "the first important discovery of silver ore was made at Schneeburg in 1470 . . . by 1474 there were 176 producing mines. . . . Silver mining flourished for 25 years or more, and then began to die down. . . . After the invention of cobalt blue* mining flourished again."

This cobalt mining became an important industry in Saxony and continued so, with more or less regularity, until quite recent years. Whether the history of cobalt will prove to be a repetition of the history of silver-cobalt mining in Saxony remains to be seen. In any event, it would be a matter of considerable importance, if some profitable use could be made of the greater part of the cobalt which is mined with silver at the present time, and which, to a large extent, remains at the smelters in an unrefined state, because of the lack of a market for it.

CONSUMPTION, PRICES AND USES OF COBALT OXIDE.

The world's consumption of cobalt oxide at the present time is about 300 tons annually. However, this estimate is necessarily more or less indefinite because of incomplete statistics and because of cobalt being used in small amounts in many widely separated parts of the world. For instance, it is known that the Chinese make use of cobalt as a colouring mattter, but the source of their supply has not been definitely ascertained.

The figures quoted below show a material reduction in the price of cobalt oxide during very recent years.

Average price of cobalt oxide in the United States, during 1900	$1.64	per lb.
" 1901	1.36	"
" 1902	1.39	"
" 1903	1.98	"
" 1904	2.05	"
" 1905	1.99	"
" 1906	2.02	"
" 1907	1.71	"
" 1908	1.61	"
" 1909	1.42	"
Present price is about	.80	"

* This was not the cobalt blue pigment, but what is known as smalt or zaffre.

The principal consumption of cobalt is in connection with the porcelain and pottery industries. It is used to overcome brownish stains, when making pure white ware, and as a colouring matter when a blue product is desired, e.g., in making blue enamels. Cobalt is said to be the only material known from which a blue colour that will withstand fire can be obtained. A very small quantity is used for the manufacture of smalt glass and in manufacturing pigments.

For the last few years the statistics regarding cobalt are incomplete. It appears to have been used more extensively in Europe than in America. The following German statistics may be of interest.*

Value of Cobalt products in			1878	$364,011
"	"	"	1879	406,679
"	"	"	1880	418,992
"	"	"	1881	419,598

PRODUCTION OF COBALT OXIDE.

Previous to the discovery of the Cobalt district, New Caledonia was the greatest producer of cobalt. This country possessed practically a monopoly of the world's production of cobalt, and this monopoly seemed so secure that in 1903 a tax was levied on all cobalt ore exported.

The ore was mined chiefly for its cobalt contents, and was all exported in the unrefined state, the price obtained depending on the percentage of cobalt oxide contained †

In 1896	4,823	tons of	ore	worth	$96,460	were	produced.
" 1897	4,757	"	"	"	95,140	"	"
" 1898	2,373	"	"	"	47,460	"	"
" 1899	3,294	"	"	"	67,200	"	"
" 1900	2,438	"	"	"	55,100	"	"

After being mined and washed the ore is said to average about 4½% of cobalt oxide. On this basis the average production of cobalt oxide from New Caledonia ores for the above years would be about 158 tons per year, while the production for 1900

* (Mineral Industry, Vol. II, 1893.)
† (Prof. Miller, Report of Bureau of Mines Ontario,—1905.)

would be only about 110 tons. The average price of the above ore would be about $20.00 per ton and the average price for 1900 would be about $23.00 per ton. According to a report to the Minister of the Colonies, on the Mineral Wealth of New Caledonia, by Mr. A. Glasser in 1904, the value of ore containing 4½% of cobalt oxide would be at that time about $67.00 per ton. The production of the rest of the world was small, New South Wales, Chili, Spain, Norway, Prussia and the United States each furnishing small amounts. A portion of that from the United States should be credited to Ontario, as it was obtained along with the nickel from the Sudbury deposits; but this production has ceased entirely, owing to a change in smelting methods.

The above figures do not agree very well with the estimated consumption of cobalt oxide, but they show a decided increase in the price of cobalt up to 1904, which increase in price would probably cause the consumption to be reduced. This comparatively small production and increasing price of cobalt oxide up to 1904 would also account for no extensive use having been made of cobalt, except in industries where nothing else could be used to replace it, *e.g.*, the pottery industry, and where the amount of cobalt used was so small as to make but little difference in the total cost of the article produced

With the discovery of the Ontario silver cobalt deposits, the conditions have been changed. The ore is mined in the first place for the silver contents, and the cobalt is a by-product. No figures are available as to how much cobalt oxide has been manufactured from Ontario ores, but it is probable that only a small portion of the cobalt mined has been refined and marketed. Quite recently the North American Lead Company, of Missouri, has added considerably to the total production of cobalt oxide by treating successfully a complicated lead-copper-zinc-cobalt ore, mined in Missouri. This production, together with that from Ontario ores, has been sufficient to cause what appears to be an over production of cobalt, but what may prove to be only a sufficient production to permit of a more extensive use of cobalt in the arts.

COBALT MINING IN ONTARIO

No statistics are published as to the actual quantity of cobalt mined in conjunction with the silver in the Cobalt district. The following is an estimate based on the total silver production.

From ores that produced 6,000,000 ounces of silver the Deloro Mining and Reduction Company received the equivalent of 250 tons of metallic cobalt, in cobalt minerals. Assuming that the ores treated represented an average value of Cobalt ores, the following would be a fair estimate of the total quantity of cobalt mined in the Temiskaming district during the years 1906–7–8–9:

Year.	Total Silver produced.	Metallic Cobalt.	Cobalt Oxide.
1906	5,401,766 ounces	225 tons	320 tons.
1907	10,023,311 "	415 "	595 "
1908	17,000,000 "	709 "	1,011 "
1909	25,000,000 "	1,042 "	1,487 "

The cobalt contents of ores shipped to Western smelters have probably been entirely lost. The same is probably true of shipments to some Eastern silver smelters, where the cobalt is largely lost or contained in a very impure speiss. Of the remainder of the cobalt mined, a portion has been worked into the form of cobalt oxide and sold; but the greater part of it is probably stored at the smelters in the unrefined state, or has been exported to European refiners. Also there have been a few shipments of cobalt ore to Europe. At the present time the International Nickel Company is probably the largest producer of cobalt oxide from these ores, and probably the most extensive holder of cobalt mineral. This Company extracts the arsenic, and a portion of the silver, at Copper Cliff, Ontario, and sends the cobalt and the remaining silver, in the form of a roasted speiss, to the United States to be refined.

The principal Canadian companies handling these ores are located at Deloro, Ontario, and at Thorold, Ontario. The former company, in addition to the cobalt residues which have been sold, has residues in storage containing metallic cobalt to the amount of about 350 tons.

SOME PURPOSES TO WHICH COBALT MIGHT BE ADAPTED.

The general result of such experiments as have been made is to show that cobalt possesses the power of forming alloys similar to those formed by nickel. For certain purposes, it is

claimed that some cobalt alloys are superior to those of nickel. For electro-plating cobalt is said to give a more silvery and less steel-like lustre than nickel, and a plating which is not so liable to peel off, as is the nickel plating. It is said that an alloy of cobalt with iron has proved to be harder than a similar alloy of nickel with iron, but was more difficult to work than the nickel alloy. Also some experiments with a cobalt-copper alloy, used for making tubes for boilers, are said to have been satisfactory. However, cobalt would require to have a very great superiority over nickel to counterbalance the difference in price between the two metals. Owing to its higher price no very exhaustive experiments with cobalt for the above purposes have been made up to the present time; or, if such experiments have been made, the results have not been published.

In addition to its being used as a colouring medium in the pottery industry, some cobalt has been employed in the manufacture of pigments. Thenard's blue and Rinmann's green are the most important of these. They are used to some extent by artists and only to a very limited amount as ordinary commercial pigments. Pigments of less importance are the cobalt yellow and cobalt red.

*THENARD'S BLUE AND RINNMAN'S GREEN.

As the object of the experiments, described below, was the production of Thenard's blue and Rinmann's green, it may be of interest to give some data in regard to these pigments. In the actual work the principal points kept in view were: (1) the cost of the materials for any colour produced; (2) the tincturing, covering and mixing powers, and the permanence of any pigments made, as compared with other commercial pigments.

The following extracts from different writers may prove to be the best description of these pigments.

"The cobalt blues work well in all media. They are unaffected by light, moisture and oxygen. The best samples of them are practically permanent, even in impure air, but ammonium sulphide tends to discolour them . . . ; they are unaffected by

* Thenard's blue and Rinmann's green are names used synonymously for cobalt blue and cobalt green. To be strictly correct, Thenard's blue is a combination of cobalt phosphate and alumina, while cobalt blue, or Wenzel's blue, is a combination of cobalt oxide and alumina.

commixture with other pigments." (Chemistry of Paints and Painting, by A. H. Church.)

"Thenard's blue: is non-poisonous, of a fine ultramarine colour. Has the disadvantage of appearing violet in artificial light. Is one of the most permanent pigments, being unaltered by acids or alkalis, and is largely used as an oil and water colour." (Thorpe, Dictionary of Chemistry, Vol. I.)

"Cobalt blue: This pigment, which is essentially a compound of the oxides of alumina and cobalt, has largely gone out of use, but that it still finds a limited application is evidenced by the fact that the author receives occasional samples for analysis. Certain shades of ultramarine blue are often sold under the name of cobalt blue." (Mixed Paints, Colour Pigments and Varnishes, p. 164, by Holley and Ladd.)

"Cobalt blue: a pigment of a fine blue colour. It is a compound of protoxide of cobalt and alumina and is used both as an oil and water color." (Henry Watts, Dictionary of Chemistry, Vol. I.)

"Cobalt green: When properly prepared, cobalt green is a pigment of great beauty and power. The deepest tones of cobalt green are almost transparent in oil. The pigment works well, is quite permanent, and has no action on other pigments. Cobalt green is, in fact, one of the too rare pigments which are at once chemically and artistically perfect; such, at least, is the conclusion I reached from my own trials . . ." (Chemistry of Paints and Painting, by A. H. Church.)

"Cobalt green: a permanent green pigment." (Henry Watts, Dictionary of Chemistry, Vol. I.)

"Rinmann's green: is a fine, permanent pigment. . . . It is not poisonous and is unacted upon by acids or alkalis, but is attacked by ammonia. (Thorpe, Dictionary of Chemistry, Vol. I.)

"Cobalt green: Rinmann's Green: Owing to its cost, cobalt green is not much used. Should it be possible to find a cheap source of cobalt, this green might come into more general use, as its permanent qualities would give it superiority over many of the other greens." (Painters' Colours, Oils and Varnishes, by Hurst.)

EXPERIMENTAL WORK IN THENARD'S BLUE.

Several processes for making Thenard's blue are described by different writers. The method described most frequently is

that in which a combination of cobalt oxide and alumina is made by heating an intimate mixture of the two substances. In some cases cobalt phosphate is substituted for cobalt oxide, and cobalt arseniate might be used to advantage, if it were not for its poisonous nature. It is essential that the heating be carried on in a neutral or oxidizing atmosphere, because contact with reducing agencies gives a dirty appearance to the colour.

What literature there is on the subject describes cobalt blue as having been made in several different ways, as above. Nothing is said about any very great difficulties, which have had to be overcome in order to produce the colour, and it seems evident that cobalt blue has been manufactured successfully, from a technical standpoint.

Actual experiments, using the methods so described, were very unsatisfactory. It seemed to be impossible to get a satisfactory colour with any proportions of cobalt oxide and alumina or aluminium hydrate. In one case, with the proportions which had given the best colour, the mixture was heated until partially fused, but the unfused remainder was still of a very poor colour. With mixtures of cobalt phosphate and aluminium hydrate, a slightly better, but still very poor, result was obtained. After this, experiments were made in which small percentages of sodium and later of magnesium salts were added. In these cases the colours produced were very much improved. In all these experiments the cobalt oxide used was about 98 per cent. pure cobalt oxide, an actual analysis giving

Cobalt Oxide	(Co_2O_3)	98 per cent., or cobalt	69.9 per cent
Nickel Oxide	(Ni_2O_3)	1.8 " " "	1.27 "
Iron Oxide	(Fe_2O_3)	very small amount	

Also, the aluminium hydrate used was chemically pure. Many writers on cobalt pigments state that the cobalt oxide of commerce is often only about 95 per cent. pure. From the methods they describe for obtaining aluminium hydrate, and because the aluminium hydrate produced by somewhat similar methods for other purposes, invariably contains some sodium, unless particular care is taken to remove it, it seems likely that they would have some soda together with their mixtures of cobalt and alumina. This being the case, it seems to be probable that the manufacture of

cobalt blue by different processes has been successful, largely owing to impurities contained in the materials used. A great many writers remark that if nickel or iron is present with the cobalt, even in small quantities, it has a very injurious effect on the colour produced. Several experiments made, using aluminium hydrate and a copper-nickel phosphate, do not seem to substantiate this. In one case a blue pigment was made in which an analysis showed the presence of nickel equal to 12 per cent. of the cobalt present. The colour was almost identical with that of a pigment produced in the same way from cobalt oxide containing very little nickel.

In the course of experiments, in which small percentages of sodium and magnesium salts were added to the mixture of cobalt and alumina, a very good colour was obtained from a mixture of

8 parts aluminium hydrate ($Al(OH)_3$)
2 parts cobalt phosphate ($Co_3(PO_4)_2 \cdot 6H_2O$)
2 parts sodium phosphate ($Na_2HPO_4 \cdot 7H_2O$.)

After heating this mixture a blue pigment with good covering and tincturing powers was obtained. However, some of the colouring matter dissolved out when it was tested with boiling water, and because of this no further experiments were made in which sodium was added to the mixture. It is probable that this fault of the pigments, produced in this way, could be overcome by further experiments. As evidence of this, a comparison with the formula of the pigment, known as ultramarine blue, may be made. A rough formula for ultramarine blue is

$4\ (Na_2Al_2Si_2O_3) + Na_2S_4$
or $2\ (Na_2Al_2Si_3O_1O) + Na_2S_4$). (Industrial Chemistry, by Thorpe, p. 210.)

This pigment is not soluble in water, its defect being that it is injured by acids, through the formation of sulphuretted hydrogen. This would seem to indicate that a combination including sodium and aluminium in certain proportions, is not necessarily soluble in water, so that it might be possible to make a good permanent cobalt blue pigment by adding sodium salts to the mixture of cobalt oxide and alumina. An analysis of a typical cobalt blue pigment, given in a "Dictionary of Chemistry and Raw Products," by Geo H Hurst is:—

Water	3.07	per cent.
Alumina	80.80	"
Cobaltous Oxide	15.13	"
Alkaline salts	1.00	"

The alkaline salts contained here might possibly be sodium salts.

In an attempt to replace the sodium salt added to the cobalt alumina mixture by a magnesium salt, a rather satisfactory blue pigment was obtained by heating a mixture of

11 parts of aluminium hydrate (A1 $(OH)_3$

1 part of magnesium-ammonium phosphate (Mg. NH_4 $PO_4.6H_2O$)

1.5 parts of cobalt oxide ($CoaO_3$)

To test how permanent it will prove to be is a matter of time. However, boiling water poured over it, on a filter paper, did not dissolve any of the colouring matter and blocks painted with it have been standing for about two months, and one such block is now exposed to the fumes of a draft closet. Up to the present time the paint has proved to be permanent, but in any event it is probable that it could be greatly improved by further experiments. The addition of a small percentage of some sodium salt with the magnesium might result in a more intense blue colour or make it possible to reduce the percentage of cobalt oxide used. Where the magnesium salt was used the pigment did not show so marked a tendency to appear violet in artificial light as where the sodium salt was used alone.

EXPERIMENTAL WORK ON COBALT GREENS

As in the case of the literature upon cobalt blue pigments, so in the case of Rinmann's green, several methods are described for producing it. The foundation of this pigment is a combination of zinc oxide and cobalt oxide. Experiments made, following published methods, were much more successful in this case than with the cobalt blue pigment

An intimate mixture of

9 parts zinc oxide (Zn o)

1 part cobalt oxide (Co_2O_3.)

heated strongly in a muffle produced a very good pigment. This product possessed excellent spreading powers and was of a light green colour. Increasing the percentage of cobalt oxide produced a darker green. So far as this pigment has been tested it has proved permanent.

From a combination of

10 parts zinc oxide (Zn O)

1 part cobalt phosphate $(Co_3PO_4)_2.6H_2O$)

a somewhat darker green colour than the above was obtained. An increase in the percentage of cobalt phosphate gave a still darker green, and the same result was obtained by replacing a small portion of the zinc oxide with alumina. Paint, made from this pigment has been exposed to the weather for about two months, and one block so painted is at present exposed to draft closet fumes. So far the pigment does not appear to have been injured, though in the latter case the oil and underlying coat of priming paint have started to peal off at the edges.

GENERAL REMARKS.

The results of the work done on the production of a cobalt blue pigment have not been by any means conclusive. Still, the general tendency of the later experiments has been to indicate that it is possible to manufacture a good cobalt blue pigment using about 15 per cent. of cobalt oxide. In regard to the green pigments it appears as though a good permanent colour could be made by using from 4 to 6 per cent. of cobalt oxide.

The cost of making cobalt phosphate from cobalt oxide would not be great, and the same can be said of the magnesium phosphate used in the blue pigment. A table showing the estimated cost of materials for both the blue and the green pigments is appended. An estimate of the working costs would be from one to three cents per pound of pigment, depending largely on the quantity manufactured.

No definite system was used for testing the tincturing and spreading powers of the pigments, or for testing their permanence. However, the history of cobalt blues and greens seems to indicate that they have been satisfactory in these respects.

In mixing any pigments which were tested as paints, boiled linseed oil and turpentine were used. These were the ordinary

commercial products as obtained in a hardware store. If making any extensive tests of the pigments, it should be remembered that an absolutely perfect pigment would not give good results if the oil used happened to be of an inferior quality or if unsuitable driers were used in preparing the oil. That the pigment be very finely ground is also of importance; otherwise the gritty particles make breaks in the paint film, which allows too great an opportunity for the atmospheric agencies to attack and destroy the paint vehicle or oil. The spreading powers of the pigment are also reduced.

BLUE AND GREEN PIGMENTS IN COMMON USE.

The better class of non-cobalt blue pigments in common use are for the most part varieties of the pigments known as Prussian blue and ultramarine blue. Paint dealers state that their is no very permanent blue pigment in ordinary use at the present time.

Thorpe's Industrial Chemistry (p. 212), describing ultramarine blue, says:—"It is a very fast colour to light, soap and alkalis, but is quickly destroyed by even weak acids." Describing Prussian blue (p. 213), the following paragraph is used: "Prussian blue is not affected by acids, and mixes well with oil, but fades a little on exposure to light. The colour is destroyed by alkalis, and consequently it cannot be mixed with any substance having an alkaline reaction. It has great tinctorial power, but is transparent and lacks body."

In regard to the non-cobalt green pigments in common use, they appear to be of a more permanent nature than are the blue pigments. A manufacturing firm states that the largest seller for out-of-door painting is known as French permanent. This is manufactured in different shades. Other more expensive green pigments are used to some extent.

MARKET FOR BLUE AND GREEN PIGMENTS.

It is very difficult to give an estimate of the quantity of blue and green pigments which might be disposed of, if successfully manufactured. It would depend largely on the quality and cost of the cobalt pigments, as compared with other blues and

greens. Some reference to the extent of the paint industry as a whole may be of interest here. It is said that the quantity of mixed paints sold in the United States annually amounts to nearly 60 million gallons. Also that one of the railway companies of the United States buys upwards of one million dollars' worth of paint material per year.

In regard to blue and green pigments, a wholesale dealer states that the large implement manufacturers buy the dry green pigment in ton lots and grind it themselves; that, outside of these large concerns, most of the green is sold, ground in oil, and that orders are sometimes received for 500-pound and half-ton lots. In respect of the dry blue pigments, he adds: "these are sold in very large quantities to the manufacturers of lithographing inks. They often import them in quantities of from five to ten tons at a time."

POSSIBLE USES FOR COBALT PIGMENTS.

Outside of the difference in the cost of the two pigments, there does not seem to be any reason why cobalt blue could not be used for any purpose for which ultramarine blue is used. It has also the advantage over ultramarine blue of not being affected by acids, so that it could be used in acidic mixtures, where the ultramarine would be useless, or at best very inferior. In regard to the extent of the use of ultramarine blue, the following is an extract from Thorpe's Industrial Chemistry (p. 212):

"Ultramarine blue is much used in wall paper and calico printing, for neutralizing the yellow colour in paper pulp, crystallized sugar and cotton and linen goods; for laundry blue, for paint, for printers' ink, and for coloring mottled soaps." To what extent cobalt salts could be made which would be adapted to the dyeing of fabrics is another question. The following extract from the above authority (p. 476) may be of interest:—

"Mordants are either of mineral or of organic origin. The former comprise the common minerals, acids, and salts of aluminium, chromium, iron, copper, antimony and tin, and, to a lesser degree, those of manganese, cobalt, nickel, uranium, vanadium and tungsten."

A mixture of cobalt blue and Prussian blue, known as cyanine has been made. It is said that the cobalt blue exerts a protecting influence over the Prussian in this case, probably by forming a

paint of film on the outside of the particles of Prussian blue. In this mixture the great tincturing power of the Prussian blue is retained and, at the same time, the paint is not so susceptible to alkaline gases in the atmosphere.

For making sign paints which have to stand exposure to the weather, and where a high degree of permanency is desirable, the cobalt pigments, both blue and green, should find a considerable market. The cobalt blue pigments in particular would have practically no competitor in regard to permanence. The cobalt pigments should also be very suitable for any purposes where a fireproof paint was needed, *e.g.*, smokestack paint, or where protection from fumes or corrosion was required.

COST OF MANUFACTURING COBALT PIGMENTS.

The cost per pound for manufacturing cobalt pigments is estimated in a table below. These costs are worked out on the basis of taking cobalt oxide at varying prices, and of aluminium hydrate at two cents per pound, zinc oxide at five cents per pound, sodium phosphate at two cents per pound, and sulphuric acid at one half cent per pound. For working expenses one and one-half cents per pound is allowed. From the above figures the cost of cobalt phosphate per pound would be equal to the cost of one half pound of cobalt oxide plus two and one-quarter cents.

For the sake of comparison some wholesale quotations on some of the better quality non-cobalt blue and green pigments are given.

TABLE OF COSTS OF PIGMENTS.

For working expenses 1½ cents per pound has been added.

Cobalt blue containing about 15 per cent. of cobalt oxide:—

Cobalt Oxide at 80c. per lb., blue pigment costs per lb.	$0.16
" " " 50c. " " " " " "	0.118
" " " 30c. " " " " " "	0.087

Green pigments containing the cobalt equivalent of about 4.8 per cent. of cobalt oxide:—

Cobalt oxide at 80c. per lb., green pigment costs per lb	$0. 10
" " " 50c. " " " " " "	0.087
" " " 30c. " " " " " "	0.078

In the above figures 1½ cents per pound has been added for working expenses. The costs of material per pound of pigment produced would be about

For the blue pigment, with
Cobalt oxide at 80c. per lb., ... 14½c. per lb.
" " " 50c. " ..... 10⅓c. "
" " " 30c. ..... 7⅕c.

For the green pigment, with
Cobalt oxide at 80c. per lb. ..... 8½c. per lb.
" " " 50c. " ..... 7⅕c. "
" " " 30c. " ..... 6⅓c. "

Some wholesale quotations on other blue and green pigments are, net:

French permanent (green pigment) ..... 7⅕c. per lb.
*A better quality green, ground in oil ..... 21c. "
Prussian blue. ..... 31c. "
Ultramarine blue (first quality). ..... 13c. "
" " (second quality ..... 8¾c. "

CONCLUSION.

According to the above estimates, with cobalt oxide at its present price, viz., 80 cents per pound, cobalt blue could not be made as cheaply as the price at which first quality ultramarine blue is sold. If the price of cobalt oxide should decline to 50 cents per pound, then the cobalt blue could compete in the market with the first quality ultramarine blue. At either price of cobalt oxide, it would be cheaper than Prussian blue, but it does not possess as much tincturing power as that pigment. On the other hand, because of its greater permanence it might not be necessary for cobalt blue to be manufactured as cheaply as the other blue pigments. It possesses the great advantage over both these pigments of not being affected by other materials in the paint composition. If the price of cobalt oxide should drop to 30 cents per pound, then the cobalt blue could compete in price with the second quality ultramarine blue and might be manufactured on an extensive scale, whereby the working costs might be reduced.

* Cost of grinding in oil is about 2 cents per pound.

It would seem as if the cobalt green pigment could, at the present price of cobalt oxide, compete in price with the better class of green pigments in common use. If this pigment could be so manufactured as to be decidedly superior in permanence or other qualities to the greens in common use—and this could probably be done—it should be possible to manufacture such a pigment profitably.

At the present price of cobalt oxide, viz., 80 cents per pound, the only field for cobalt pigments would be for higher classes of work, where original cheapness is not the main consideration. A consideration of the difference in cost of the pigments, taking cobalt oxide at 80 cents per pound, and at the assumed price of 30 cents per pound, will show a reason why such pigments would be but little used when cobalt oxide was worth upwards of $2 per pound, as in 1906.

PRELIMINARY DEVELOPMENT WORK.*

By ALAN M. BATEMAN, School of Mining, Kingston.

Probably no mining operations have excited as much interest in recent years as those of the Cobalt and other silver camps in Northern Ontario. It is not always remembered, however, that mining, properly so-called, must be preceded by the long and careful work of initial development. In a district where, under the existing mining laws, thousands of claims are staked that never by any possibility become mines, it is extremely important that this preliminary work should be done as wisely and cheaply as possible. But this is just the class of work of which it is extremely difficult for purchasers of mining properties to gain any specific and accurate knowledge. Very little has been written on the subject either in text-books or in periodicals, while the need for such information is very apparent. The writer, therefore, here presents some facts derived from several seasons' personal experience of work of this nature.

We will assume that a group of mining claims in the silver district of Northern Ontario has been acquired by individuals who are willing to expend sufficient capital to ascertain whether or not these properties will prove valuable as mines.

On the properties one or two small veins may in each case be discernible on the surface, but probably little if any development work will have been undertaken. The initial step then will be the appointment of a competent man to take charge of the work of development. He will necessarily first require to ascertain the facilities for taking in supplies to the camp. The question of winter or summer transportation must be considered. Winter transportation is by far the quicker and cheaper method, when possible. Teams may be hired at a cost of $15 to $20 per day and are capable of hauling on sleighs two tons a distance from 20 to 25 miles per day, according to the state of the roads. This haulage

*Awarded Prize in "Students' Competition 1910."

should be done in mid-winter, for the roads then are at their best. Meanwhile a cabin should be erected on the claim to house the supplies until they are required upon the opening of spring. Winter transportation of this sort by team costs about $1.10 ton per mile.

In summer the water routes will probably be followed and supplies taken in by canoe. The carrying capacity of canoes, manned by two men, varies from 300 to 1,000 pounds. In straight stretches of water 30 to 40 miles a day may be covered, but if there are many portages progress will be limited to from 10 to 20 miles. Experienced canoemen should, of course, be employed, and may be hired at the rate of $2.50 to $3.00 per day. The cost of canoeing supplies in a country where portages are somewhat numerous is about $2.85 per ton per mile. If preferred, it is now possible to arrange for the transportation of supplies on a contract basis, the contractors assuming all responsibility for safe delivery. Thus last season supplies delivered to the writer's camp were carried a distance of 40 miles at the rate of $5.50 per 100 pounds.

In such a district where transportation is difficult and the cost is high, judgment must be exercised in selecting supplies for a party. For example the weight and bulk of some supplies such as canned goods are disproportionate to their nutritive value as compared with other food stuffs. The following is a list of necessary rations, basing the estimates on the requirements of one man per week. It is unnecessary to add that supplies of the best obtainable quality should alone be purchased:—

Bacon	5.5	lbs.
Flour	4.2	"
Sugar	3.5	"
Beans	2.	"
Rice	1.	"
Dried Fruits	1.	"
Oatmeal	2.	"
Fresh Onions	1.	"
Lard	2.	"
Butter	1.	"
Tea	½.	"
Cream	2	cans.

Roughly speaking in estimating the food requirements of a party for a given period of time, an allowance of about $3\frac{1}{2}$ pounds of solid food per man per day would be about correct. The general cost of feeding a party ranges from 80c. to $1.00 per man per day.

The necessary equipment for initial claim development will include a blacksmith's outfit, consisting of hand-bellows, anvils, hammers, cutting-tools and coal or charcoal; a drilling outfit of $\frac{7}{8}$-inch bar steel, striking-hammers with extra handles, dynamite, fuse and caps; a shovel and pick for each man; and also a cook's outfit and sleeping equipment of tents, blankets, tarpaulins, etc. A camp spot should be chosen convenient to the canoe route and to the work, and near good drinking-water. Thus with supplies and equipment on the ground actual work may be initiated.

Preliminary operations should take the form of extensive stripping and trenching. The veins already discovered should be laid bare as far as they extend along the strike. Then the properties should be carefully examined and the direction of all veins and disturbance seams noted, especially the *areas* of disturbance. Trenches should be cut at right angles to these in the hope of uncovering more veins. The subsoil is not usually very deep and consequently trenching is not a difficult undertaking. The rock formation should also be carefully noted, to avoid loss of time in working in unproductive formations.

The mineral in the Montreal River mining district is mostly associated with diabase of the Post-Middle Huronian age, also with the Lower Huronian conglomerate, and to a very minor extent, Keewatin. Therefore, all trenching operations should be confined to these rocks. They are easily distinguished. The diabase is a heavy, dark, basic, igneous rock, distinctly crystalline, medium-grained and with the typical ophitic or lath-like structure of the feldspar. It is sometimes found in the form of a coarse-grained granitic mass, called gabbro by the prospectors, and is found in the same flow as the diabase. The conglomerate has a dark matrix, enclosing pebbles and boulders, generally rounded by water-action and often elongated. The pebbles are of Laurentian age, sometimes Keewatin.

The veins occur mostly as narrow contraction-fissures filled with a gangue of calcite, often quartz, or both. The quartz in

many cases adheres to either wall in the form of dog-tooth crystals projecting inwards and penetrating a central portion of calcite which appears to be secondary. Generally, the calcite fillings are the most productive; but the valuable metal has also been found in the quartz. These narrow veins are generally decomposed for a short depth below the surface and are easily recognized during the trenching operations. There is another type of mineral-carrier to be looked for although its economic importance is not yet established. This is the so-called Aplite dyke. These dykes are acidic, generally reddish-pink in colour, of medium fine-grained texture, composed of feldspar, mainly oligioclase and albite, with calcite and quartz. Sometimes the central part of the dykes is filled with calcite which is considered more favourable for the maintenance of continuous ore values. Their width varies from a mere crack to two or three feet. The minerals found in all the veins consist usually of chalcopyrite, pyrite, specularite, smaltite, niccolite and silver, the latter both as native and sulphide. Should a contactof two rock formations be noticed it is well to work along it with the prospect of finding a contact-vein.

The ground should thus be systematically trenched on the surface, and as each vein is found it should be stripped along the strike. A map of each claim should be made, outlining the geological formations and contacts, and each vein indicated thereon after its discovery, the width and dip and mineral contents noted and numbered for future reference. The map should also show all trenches, pits, and prospect-shafts. A tracing should be made and kept up to date and each month a blue-print taken from it and sent to the owners together with a monthly report of work. By this means the proprietors will be enabled to follow closely the progress of the work.

The surface having been thoroughly prospected by trenching, the next step will be to sink test-pits to a depth of a few feet on the more promising veins. This procedure will enable the vein to be seen at a depth where it is more solid, and to some degree, will indicate if the values are continuous. In this hard rock, two men will sink from $\frac{1}{2}$ to $\frac{3}{4}$ of a foot per shift, and ten feet of drilling per shift by two men is considered good work. These pits need not be sunk to a greater depth than that from which a man may throw out the muck with a shovel. If it is desired to go a few feet

deeper than this, a bench should be cut out to make a throwing-stand, thus saving the erection of a windlass. Sinking by hand labour to shallow depths will cost from $12.00 to $18.00 per foot. Assays should be taken of all the veins and systematically recorded, and if the work is on a large scale it would be advantageous to instal at the claim a small assay outfit.

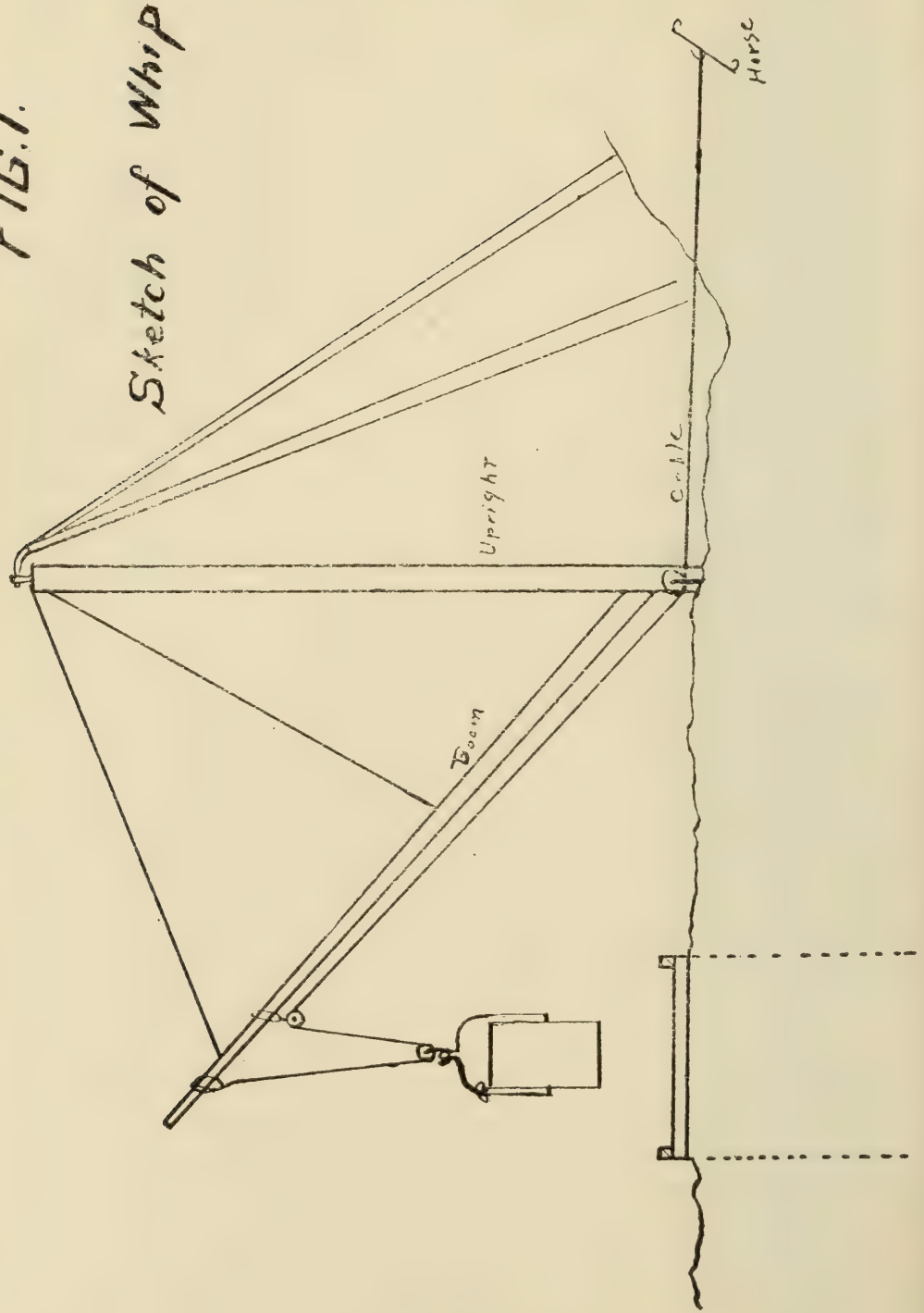
Development operations should now have reached a stage when it should be possible to judge whether further expenditure were justified. If it be decided to continue, the test-shafts may then be sunk to depths of fifty or a hundred feet and drifting carried from them. The work may either be undertaken by day labour or let by contract. The advantage of "day labour" is that operations may be discontinued at any moment; but, if no very extensive work is contemplated it may profitable be let to a contractor. The usual price paid on a sinking contract is from $28.00 to $35.00 per foot for the first fifty feet, and for the next fifty feet at the rate of $40.00 to $45.00 depending on locality, water, nature of ground and amount of work to be done. Drifting at a depth of 50 feet costs from $22.00 to $28.00 per foot.

For prospect work a drift of 6 x 5 feet, and a shaft of 7 x 5 feet, are fair dimensions; but should this shaft be sunk with a view to its permanent utilization, it would of course be necessary to increase these dimensions. A stipulation with the contractor should have been made moreover that, before the work is measured up, the walls shall clear the required distance on four sides from a plumb or suspended centre-line. Again to avoid possibilities of difficulty the contractor should be obliged to file all pay-cheque receipts, showing that he has paid his workmen before a final settlement is made with him.

If, however, it is decided to undertake the work by day labour, the shaft should be sunk at the most favourable showing of the vein, having regard, however, to the slope of the ground for rock dump requirements. If the ground be flat the collar of the shaft may be built up for about three feet and filled solid with the waste rock, and another three feet may then be added to afford more room. The collar should be built strongly and wedged tightly so that no loose rock may fall in on the workmen. When the shaft is down about ten or twelve feet a hand-windlass should be erected. This is simply a central drum with handles on either end, revolving

FIG. 1.

Sketch of Whip

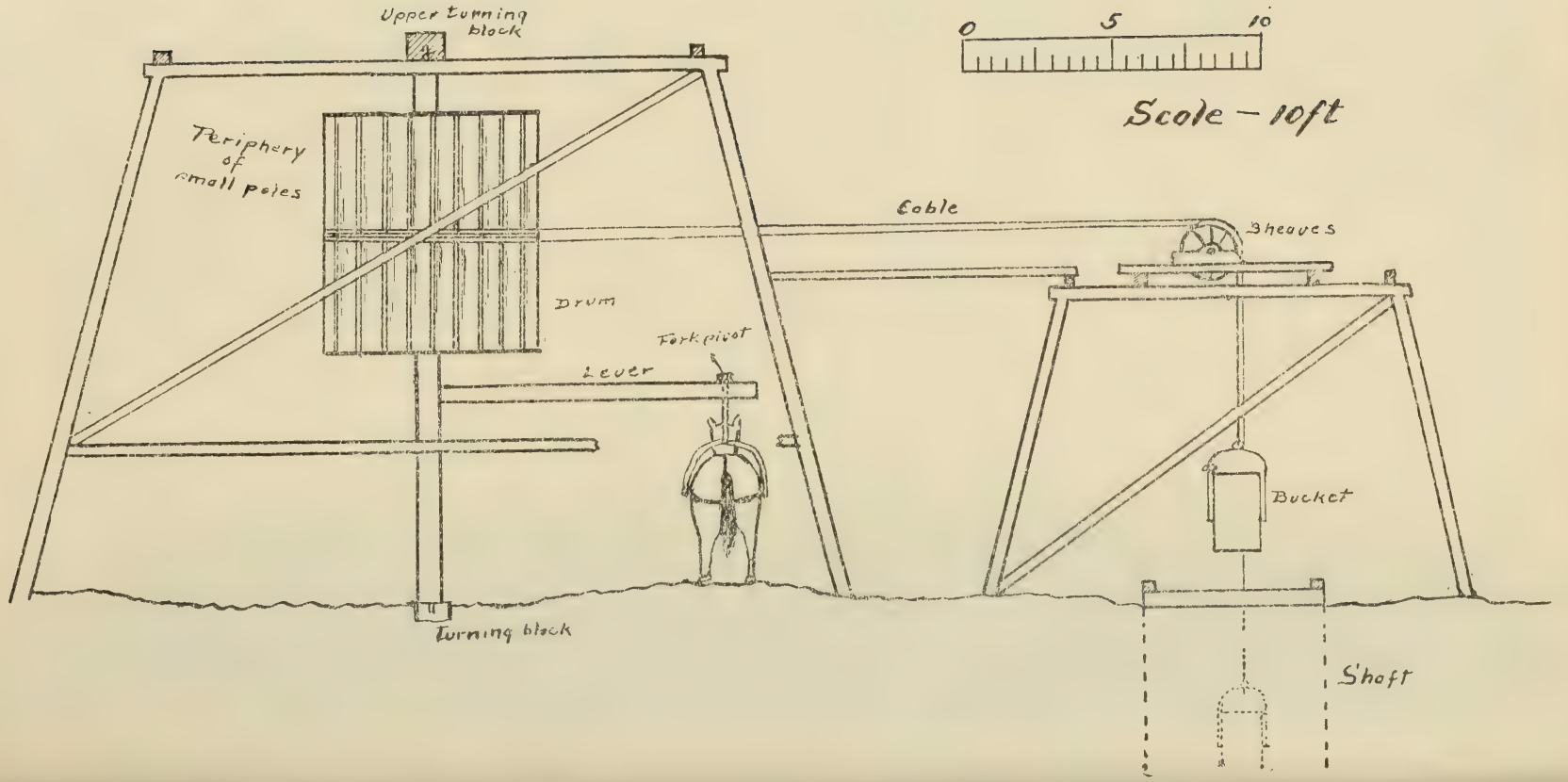


on two notched uprights, and fitted with a rope and small bucket; a smaller rope, two turns of which are passed around the drum, serves as a brake in lowering. This windlass can be made and fitted up by a couple of men in less than a day, and can be used efficiently to a depth of about 40 feet, when a whip or whim should be erected. A whip (see figure 1) consists of an upright timber held in place by two other timbers and supporting a swinging boom. The cable is fastened to the boom and carried down, thence to the bucket through a block, thence again back and down to the foot of the upright where it is drawn directly by a horse. When the full bucket is raised the boom is swung over the dump, and the bucket emptied. For the whim we could have a swinging boom, or else three timbers erected tripod-wise, over the mouth of the shaft, suspending a pulley through which passes the cable to the drum of the whim. If the shaft is of larger dimensions two buckets should be employed and for this another style of whim would be better. (See figure 2). A head-gear about ten feet high would have to be erected over the shaft, and to one side another framework supporting a drum, vertical and overhead. The drum should be six to eight feet in diameter, easily turning and a lever projecting out from it, from one and a half times to twice the diameter of the drum, and at the height of a foot over a horse's head. An iron fork with its handle free to turn in the lever-arm, should be placed in the end of the lever with the arms projecting over the horse's back; to these the tugs are attached. The cable should be given four turns around the drum and each end lead directly over vertical sheaves so that when the horse travels in one direction he raises a full bucket and lowers an empty. When the other bucket is to be raised the horse driven in an opposite direction revolves around the horse-path while the fork turns in its socket. A short rope fastened above and hooked on to the lower edge of the bucket, which is then lowered away a little, causes it to swing to the side and tilt, discharging into a chute or car or wheelbarrow as the case may be. For this method of dumping a small door should be dropped over the shaft-mouth to prevent any accident from rock falling on the workmen. A whim of this description may be installed in a few days at a cost of about $75.00, when it is not required to pay for timber, and can be used to a depth of 250 feet. The two buckets of

FIG. 2

Sketch of Horse Whim

using 2 buckets



course do not balance the load; but the horse's load is lighter, and twice the time is saved when a bucket is raised and lowered by the same operation.

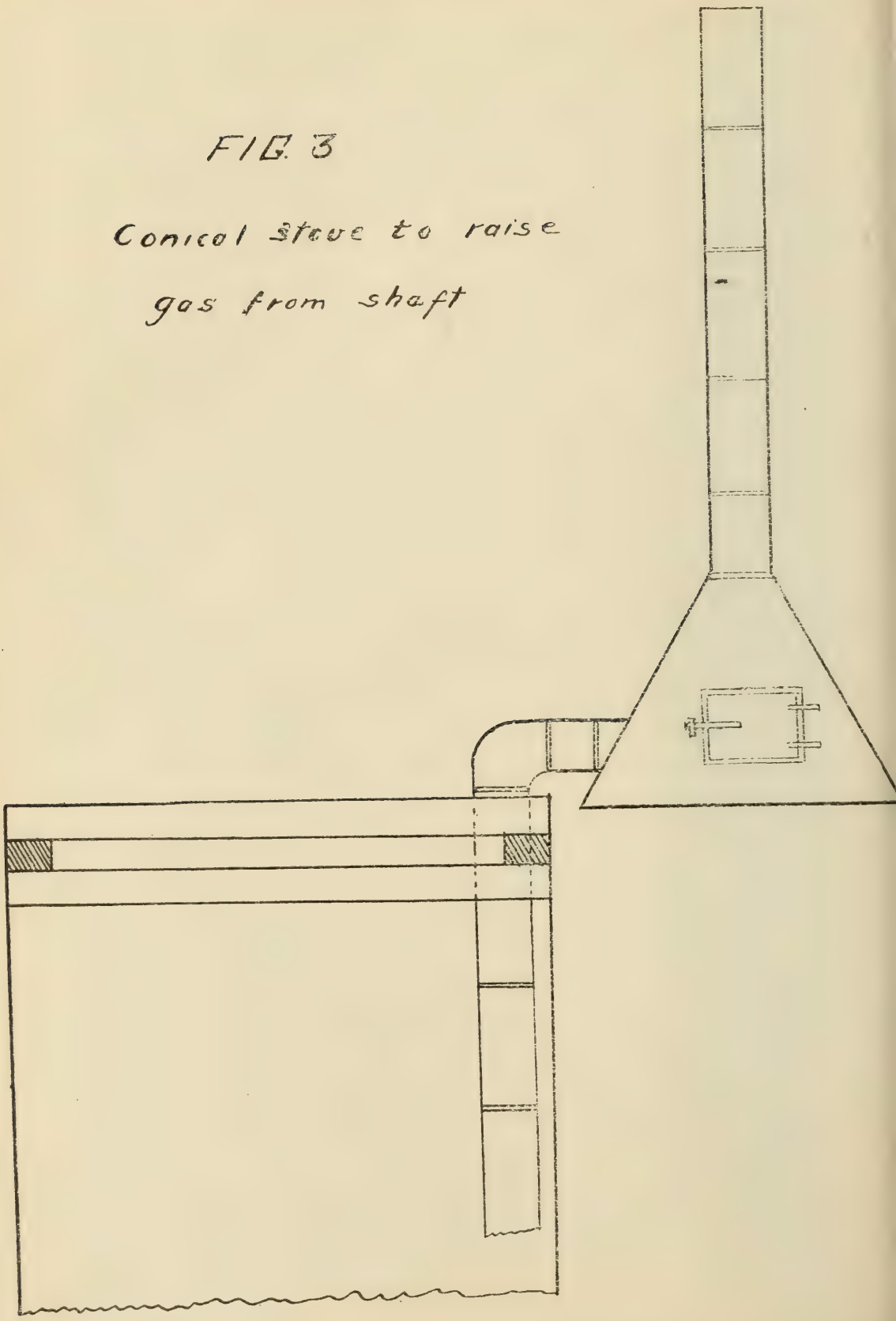
Water in the shaft may be removed by bucket or a small pump. Small pumps are made of the same type as a boiler-feed pump; but are worked by a hand-lever. They occupy but little space and can be easily moved, raised or lowered when desired and are capable of pumping against a head of 100 feet.

A difficulty to be encountered in hot summer weather, is dynamite gas which clings to the damp walls and bottoms of prospect shafts. Before a depth of 25 feet has been reached the gas will quickly pass off, or a pail containing a fire of dry wood can be lowered to assist in driving it out. At greater depths more efficient means should be employed. One method is to employ a conical sheet-iron stove with a tight-fitting door and bottom. (See figure 3). It tapers up to a small chimney of stove-piping 8 or 10 feet high to give sufficient draught. On the side, near the bottom, is a hole to which can be fitted a line of stove-piping to drop down the shaft so that when a hot fire is started the only draught obtainable is through the piping from the bottom of the shaft. By this means a hole 75 feet deep can be cleared of gas in three quarters of an hour. A tripod of light poles, fifteen to twenty feet high should be erected over the stove so that when a round is to be fired the piping may be disconnected and hoisted clear of the flying rock, by means of a rope passing through a pulley in the tripod. It can be hung up in this position so as to be out of the way when not in use. Another method is to make a wooden fan, geared to a high speed, rotate inside a box. The fan is operated by a crank and draws air from the bottom of the shaft through a pipe made of heavy canvas sewed tightly and varnished to prevent leakages. The stove, however, has been found to yield the best results. In one-opening prospect shafts gas may prove a fruitful source of danger. A reference to Mr. E. T. Corkill's Report to the Government of Ontario on Mine Accidents for 1909, will show that in this district death has resulted from suffocation by dynamite gas in a shaft of but 50 feet in depth.

If the ground be loose, timbering will of course be necessary; but for preliminary work it is needless, unless for the protection of the workmen. In this district good timbermen are

FIG. 3

Conical stove to raise gas from shaft



not common and consequently cribbing is to be preferred to square-sets, since the former may be more easily and quickly installed by less skilled labour. The collar about the shaft as already mentioned will now be continued down, and the cribs should be wedged tightly in place and every little distance placed in hitches.

The ore deposits of this country have not as yet been found to be deep, so to begin with a shaft of eighty-four feet will be sufficient, leaving a sump of ten feet. Drifting on the vein may then be carried in either direction. In preparation for this a platform should first be built at a depth of about three feet below the level of the drift, and stations of eight feet high then cut out. Two men engaged in drifting should be able to progress at the rate of half to three-quarters of a foot per shift. Fifty feet in either direction will be a sufficient distance to drive, and the veins should be closely watched as the work advances. Planks should be laid along the floor and the ore wheeled out in barrows and dumped into the bucket, the top of which, when the bucket is resting on the platform, is level with the bottom of the drift.

THE WABANA MINES AND HAULAGE SYSTEM.

By G. A. GILLIES, McGill University Montreal.

The Wabana iron ore deposits lie on the north side of the island in even and unbroken beds, which dip at an angle of about 8 degrees towards the north, and are separated by beds of shale and hard sandstone. There are eight beds in all, but only two of these are of sufficient thickness and area to have a commercial value. The lower bed is about 8 feet thick at the outcrop, which is about $3\frac{1}{2}$ miles long (see sketch No. 1), and has an inland area of about $1\frac{1}{4}$ square miles, the analyses showing it to be hematite, averaging from 54% to 59% metallic iron. The upper bed has an inland area of about $\frac{3}{8}$ of a square mile, is 6 feet thick, has its outcrop equally defined, and is slightly higher grade ore.

UNDERGROUND MINING

The ore was at first won by surface stripping, which was continued until the burden reached a depth of from 14 to 16 feet. Beyond this depth it was found cheaper to mine the ore underground.

The two slopes—the western, known as No. 1, and the eastern as No. 2—are about three quarters of a mile apart and follow the dip of the ore bed in a direction parallel to the magnetic north. Levels are conducted from these slopes, and the ore is secured by the room and pillar method. In 1893 it was estimated that the island contained, exclusive of submarine areas, 35,000,000 tons of ore, barely one-fourth of which has been mined to date.

SUBMARINE MINING.

In 1905 the Nova Scotia Steel & Coal Company decided to extend their operations into the submarine area, and thus prove

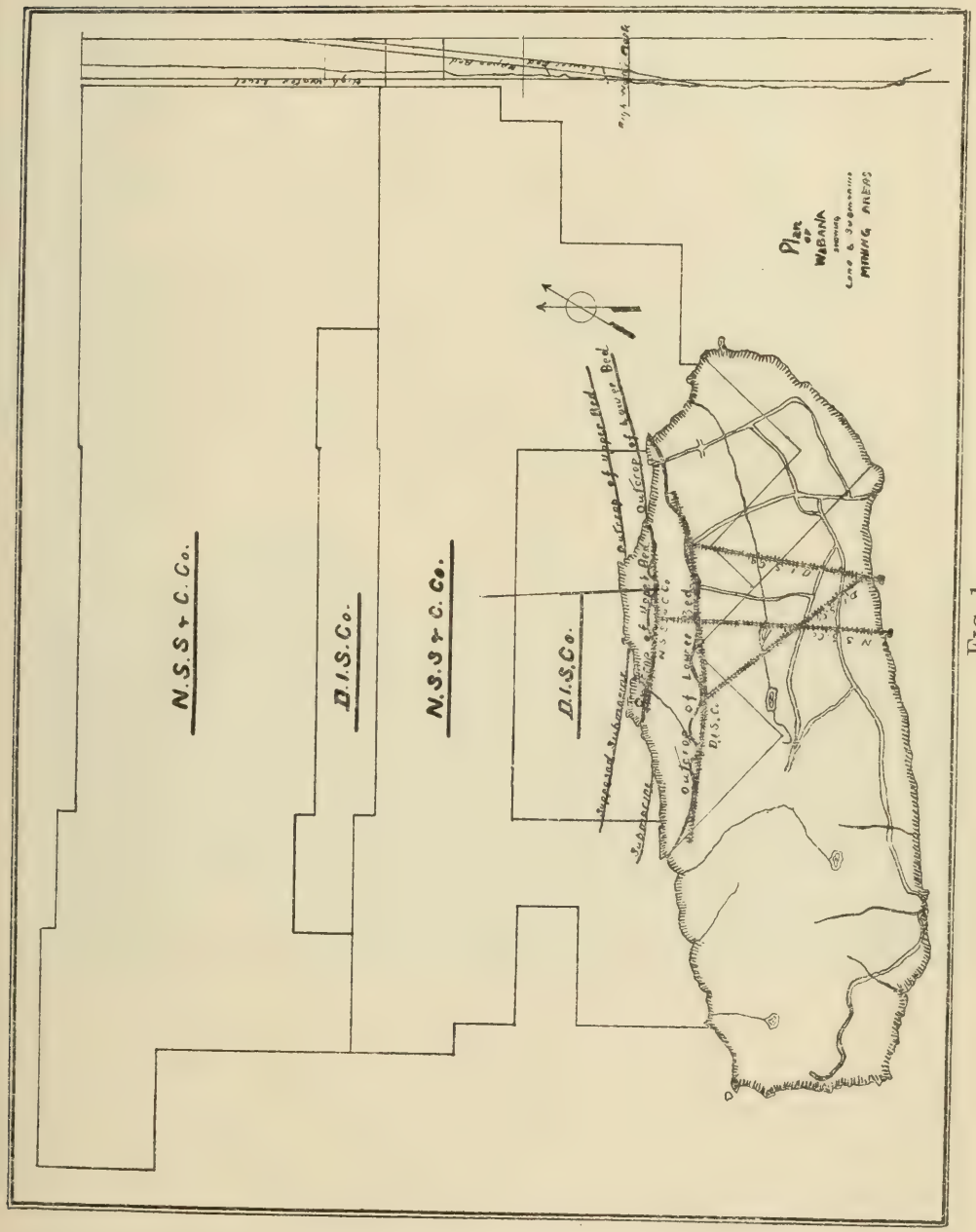

N.S.S & C. Co.
D.I.S.Co.
N.S.S & C. Co.
D.I.S.Co.
Plan of WABANA Iron Ore & Steamship MINING AREAS

FIG. 1

conclusively the correctness of their conclusions regarding the quality, quantity and accessibility of this ore bed.

In January, 1909, the southern boundary of the Nova Scotia Steel & Coal Company's area was reached, at a distance in of about 4,000 feet, an average advance having been made for 31 months of 127.9 feet per month, with 270.1 as a maximum and 42.5 as a minimum. This latter was in August, 1907, when the first fault was passed, an upthrow of 29 feet leaving only 85 feet of covering between the workings and the sea. Since then eight faults have been passed through—No. 1, an upthrow of 29 feet; No. 2, a downthrow of 13 feet; No. 3, a downthrow of 0.9 feet; No. 4, a downthrow of .04 feet; No. 5, a downthrow of 3.5 feet; No. 6, a downthrow of 3.3 feet; No. 7, a downthrow of 25 feet; No. 8, an upthrow of 6.5 feet. Between faults Nos. 7 and 8 the grade was increased from 12 to 20%, but after passing No. 8 the normal dip of 12% was again encountered

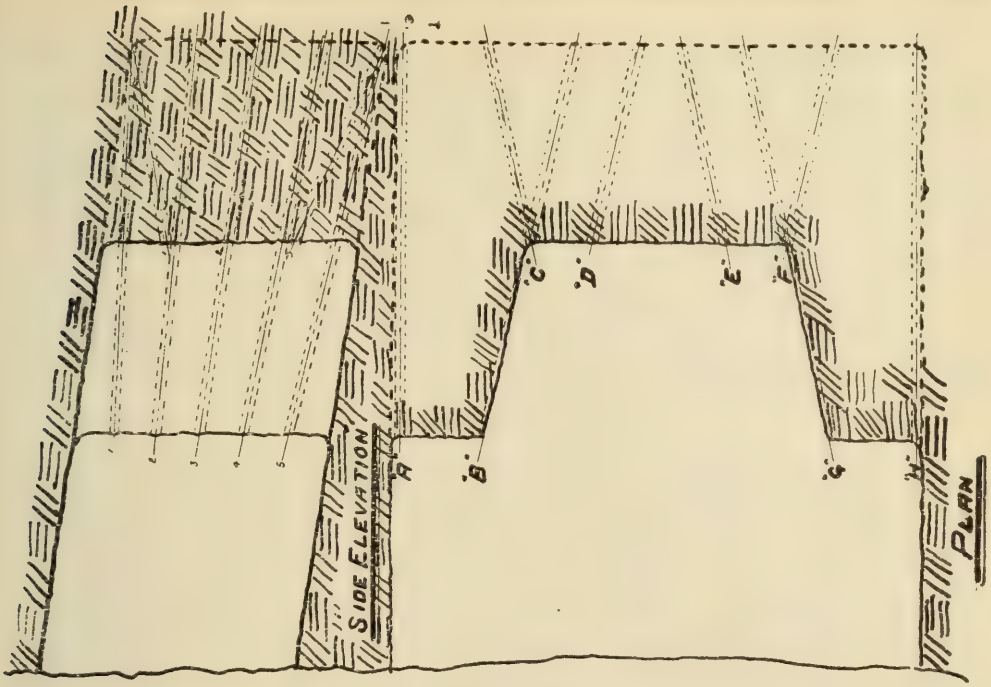
DAMS.

To safeguard the underground workings of No. 2 slope from a possible flood, dams were built directly underneath high water line. Here the width of the slope was gradually decreased from 15 feet to 6 feet, and then again increased to 15 feet, the height remaining unaltered. The slope was then lined with concrete, large pipes for air and water being embedded in the floor and a smaller one for air in the roof. A set of 10″ x 10″ stop logs were fitted in the opening, then removed and piled up in a convenient position alongside.

The object of these dams and the reason for placing them here was, as far as the writer could learn, as follows:—First, it was known that the submarine slope would encounter faults; second, that the covering between the roof of the slopes and the floor of the sea was very thin.; third, that the land workings, if extended to the shore, would be 68 feet below high water level, and that, if a flood should occur in the submarine slopes, a large part of the land workings must be abandoned.

The slopes are driven double entry down to the second fault and single entry from the second to the face. These are ventilated by one 4-foot and two 3-foot Sturtevant direct-connected air driven fans. The 4-foot fan is placed in the air course at the bottom of the old workings.

Headworks, No. 2 Slope.



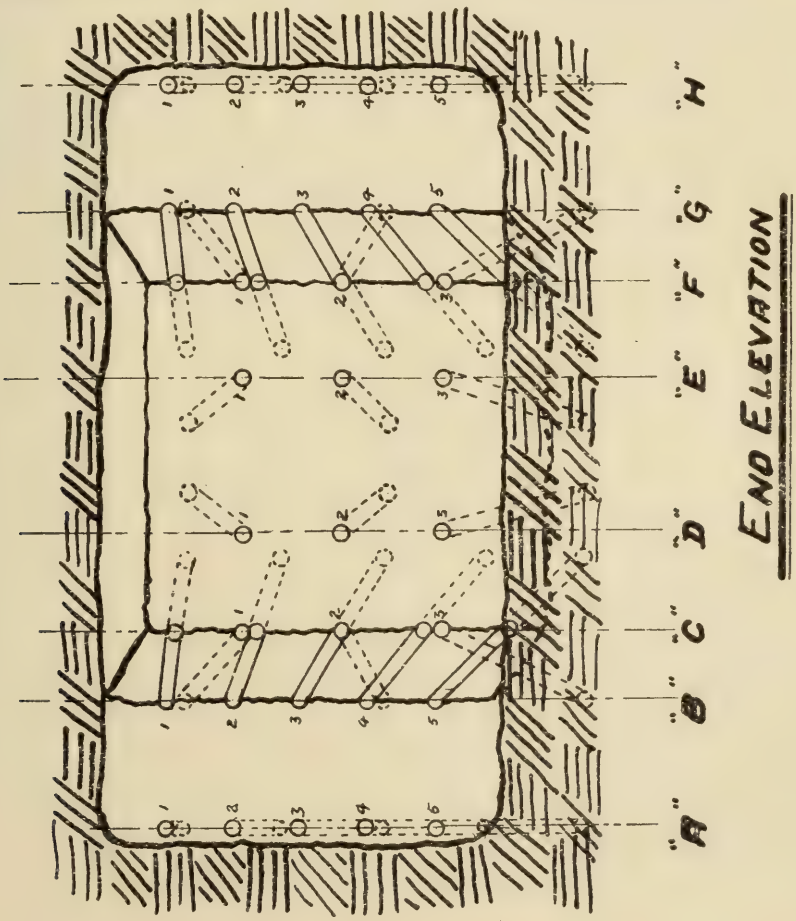


FIG 2.

The two 3-foot fans are used to exhaust the air from the long length of single entry. One fan is placed at the upper end of the 15-inch spiral rivetted pipe 1,000 feet long. The second fan is connected on one side to the lower end of this pipe, and on the other side to a similar pipe 18 inches in diameter, which extends to within 30 yards of the working face.

The slope has a width of from 13 to 15 feet and a height equal to the depth of the ore body. In advancing it, three 8-hour shifts are worked

HOISTING.

The hoisting is done in three stages. The hoist, a 14 x 18 inch double cylinder engine, installed for No. 2 slope, works the first stage. A 10″ x 12″ double cylinder Lidgerwood hoist operates the second stage. This hoist is placed near the shore and its cable enters the slope through a shaft sunk for this purpose. The third stage has an $8\frac{1}{4}$″ x 10″ double cylinder hoisting engine and is driven by compressed air.

Protection is afforded the workmen in the slope from runaway cars by a safety switch on the surface, a swinging gate in each hauling stage, and by two Sampson posts at the working face. The posts of the swinging gates extend well into the floor and ceiling, are firmly braced from the walls, and each is operated by a boy. The Sampson posts are placed about 50 feet apart and as the face recedes the rear post is taken down and set up 50 feet in advance of the other.

HEADWORKS AND TRAMLINE.

The ore, on reaching the surface, passes through a crusher, then over a picking belt into a chute, where it is loaded into steel cars holding 1.8 tons, and hauled to the south side of the Island on a tramline operated by an endless cable.

This tramline is in the form of the letter "T," the western branch running to the headworks at No. 1 slope, and the eastern to those at No. 2, with the long leg reaching directly south across the Island to the southern shore. It also has a 2-foot gauge and two tracks, the one for loaded cars being laid with 28 pound rails, while the one for empties is laid with 18 pounders.

In order to describe the working system, the tracks are here indicated by letters. At the intersection of the branches, and

looking south, the right-hand track is "A" and the left-hand "F"; looking west, the left-hand track is "B" and the right-hand "C"; looking east the left-hand track is "D" and the right-hand "E." Tracks "A," "B" and "D" are for empties, and tracks "C," "E" and "F" are for loaded cars. (See sketch No. 3.)

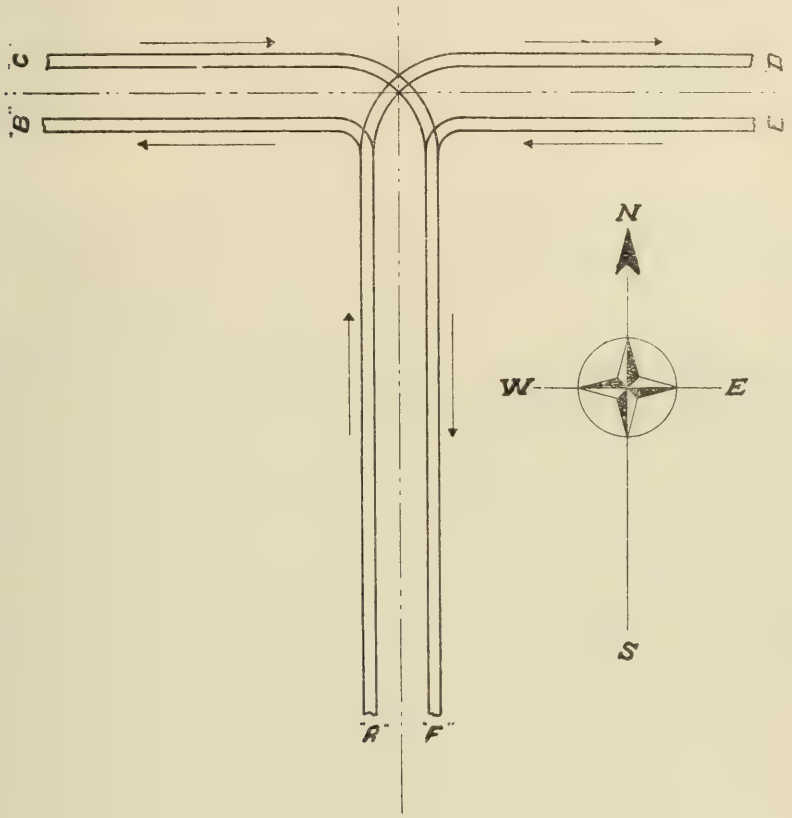


FIG. 3

These tracks roughly follow the profile of the island, are 3 feet apart, and are laid on long ties, which extend under both tracks.

The cable, a 1-inch diameter plough steel Lang Lay, is $6\frac{3}{4}$ miles in length. It rests on wooden rollers set 25 feet apart, supplemented by cast iron wheels placed at the crest of each rise, and requires about 15 h.p. to overcome its own friction.

Its course is as follows:—Starting at the south shore, it runs north along "A," round an idler, and west along "B" round a second idler and east along "C" and "D" round a third idler, and west along "E," then round a fourth idler, and south along "F" to the edge of the cliff.

Here it passes over another pulley and down 220 feet to the driving drum, which is situated on a pier at the base of the cliff. From the drum it goes to a tension adjuster, then up the cliff over another pulley, and back along "A."

The cars are switched from "A" to "B" or "D" by means of an artificial grade. The cable hauls them to the top of this grade, their grips are then loosened from the cable and they run, by gravity, over a switch to either "B" or "D." (See sketch No. 4.)

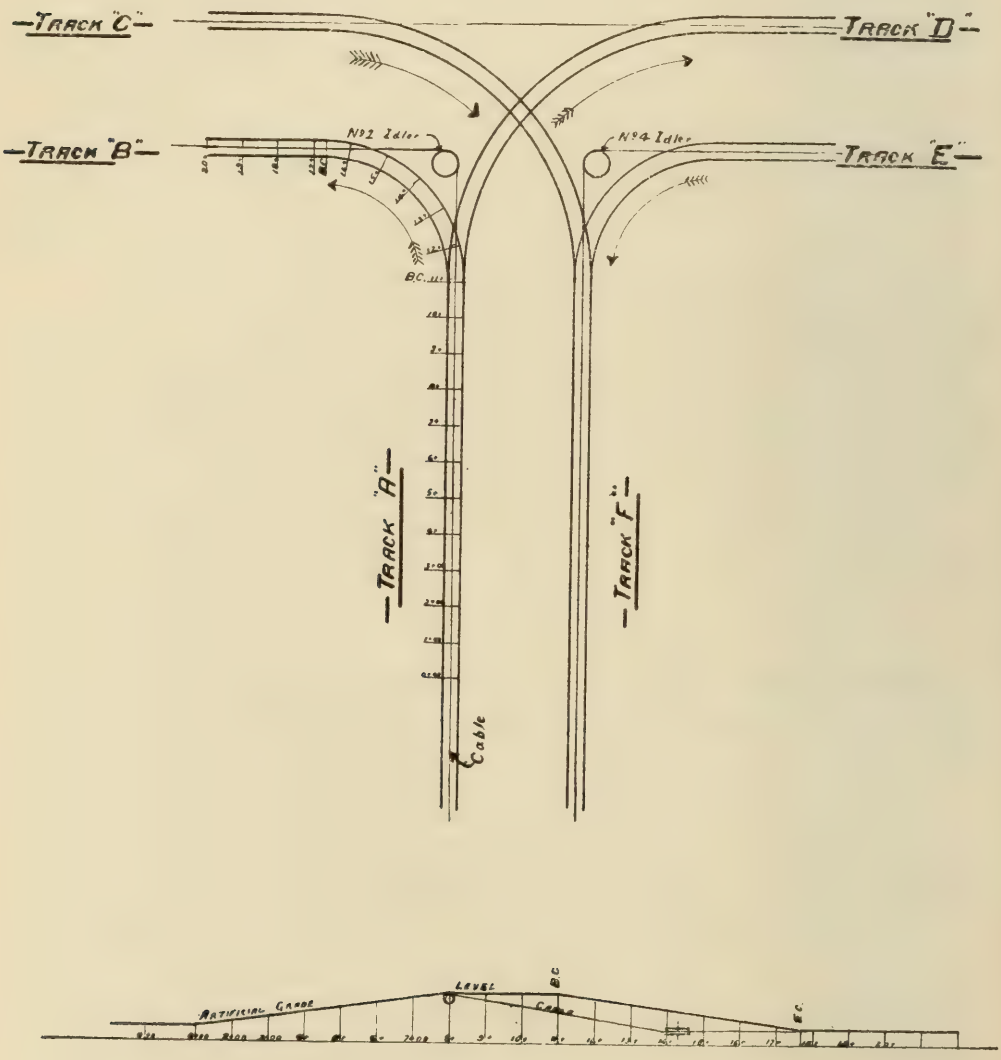
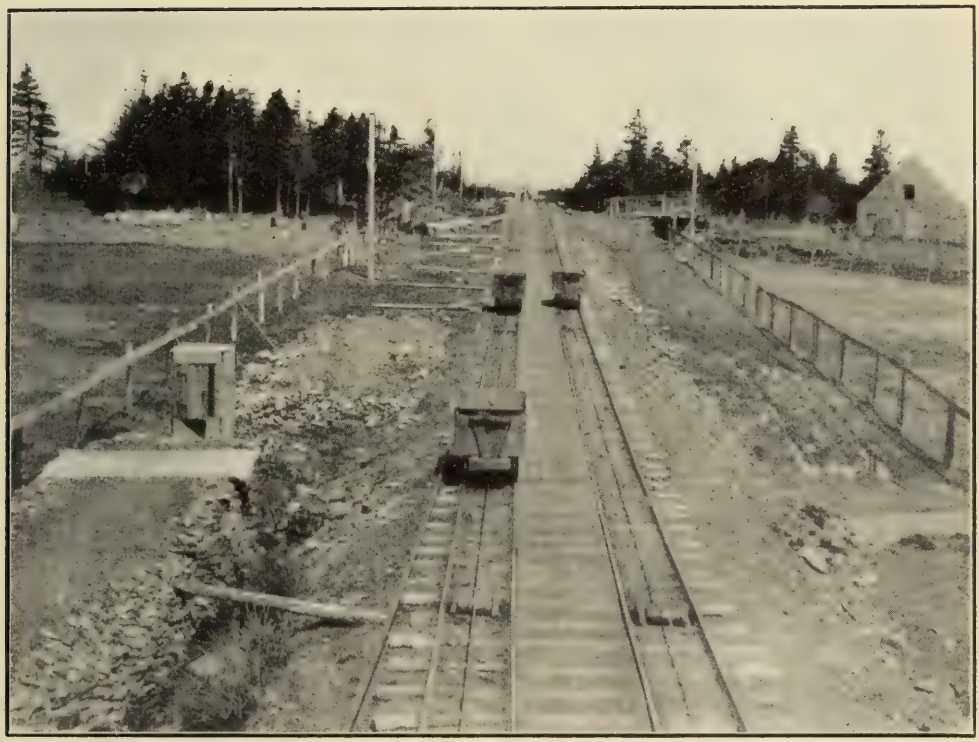


FIG. 4



Tramline looking North.

The cable itself passes underneath the curve at "A," round the idler and up through the track at the "B" end of the curve, where it is again gripped by the cars. The same method is employed in switching full cars from "C" and "E" to "F", the top of these grades being at "C" and "E" and their lower ends at "F."

By this system a man is required at each end of every curve, one at the beginning to release the grips and another at the end to refasten them to the cable

At the south or pier end of "F" the full cars are hauled by the cable out on to a level piece of track which runs alongside the ore bin and is supported by timber. The clutch is then released and they are pushed by hand into an automatic tipple. After passing the tipple, the empty cars run down a grade, through a switchback on to track "A," and are then attached to the cable for the return journey.

The power to operate this tramway is supplied by three 42-h.p. vertical boilers and a 120-h.p. engine geared down to the driving drum, in order to give the cable a speed of 240 feet per minute. At this speed, and with the cars spaced every 80 feet, it has a capacity, including stops, of 3,000 tons per day of 10 hours.

The profile of the Island at the pier end of the tramline slopes rapidly towards the cliff, which is here about 150 feet high, necessitating a trestle 85 feet in height, to support the tracks, which are brought out to the face of the cliff on the level and terminate in the switchback as described in the paragraph on Switching.

The ore bin extends along the east side of the trestle and has a capacity of 40,000 tons. In building it advantage was taken of a small ravine, which was enlarged and the mouth closed up with cribwork till it resembled a rectangular hopper, the bottom terminating in a chute connecting the conveyor placed underneath the bin in a passage partly built in the cribwork and partly blasted out of the side of the cliff.

Under normal conditions, the ore from the tipple is discharged through a chute into the bin, but when the latter is nearly full, the ore is diverted on to a belt conveyor.

LOADING APPARATUS.

The conveyor for loading the ore boats consists of an endless chain of steel, "U"-shaped buckets, each about 36 inches long and 18 inches deep by 24 inches wide, runing on a wooden track faced by 3″x3″ angle iron. It is about 70 feet above low water level and 500 feet in length, and discharges into a bin holding about 200 tons, which in turn discharges through a chute into the ore boats. This chute has a 40° slope and is counterbalanced so that one man can raise and lower it.

The inner end of the loading conveyor is supported by the cliff, the intermediate points by trestles, and the outer end by the 200-ton bin, which in turn is held up by heavy trestlework. All the trestles rest on piles surrounded by cribwork filled with stones, the intermediate ones having fewer piles and smaller piers.

An ordinary hoisting engine, placed at the outer end of the conveyor, is used to operate it. This engine is geared direct to the conveyor shaft, and is capable of loading 4,500 tons per hour. A 7,000-ton boat has been loaded by it in three hours, more than half of this time being lost in warping the vessel along the pier in order to bring the hatches opposite the loading chute.

DOMINION No. 2 COLLIERY OF THE DOMINION COAL COMPANY.*

By A. G. Haultain, McGill University, Montreal.

The mines of the Dominion Coal Company, situated at the east of Canada on Cape Breton Island, produce at least half of the entire Canadian output. The Company controls the whole of the Lingan, Victoria and Glace Bay seams, as well as areas at Point Aconi and in the Morien basin. The names and thicknesses of the principal seams of the Glace Bay area are given below

NAME	THICKNESS.
Hub	9′ 6″
Harbour	5′ 6″
Phalen	8′ 7″
Emery	4′ 7″

Phalen is a fat, bituminous coal of a high-heating value, and when burnt in retort ovens makes good coke and yields profitable bye-products. †The following table presents the results of some analyses of Phalen coal.

Moisture	0. 5—1.0
Volatile Matter	25.13%—37.26%
Fixed Carbon	57.37%..71.22%
Ash	2.19%—9.63%
Sulphur	2.47%—1.1 %
Specific Gravity	1.28%—1.33%
Theor. Evap. Power	7.88 —8.78

*Awarded a Prize in the "Students' Competition 1910."

†"Mineral Resources of Canada—Coal".—Geological Survey of Canada.

The seams in the Glace Bay area occur in a saucerlike formation, the outcrops showing as a series of concentric rings, with their centres out at sea. Except in the case of Caledonia Mine, no faults or foldings have been encountered, but in several mines the seams have pinched down to less than a foot in thickness. The largest and most up-to-date colliery is Dominion No. 2, draining on the Phalen seam. Shaft sinking was started in 1899 on the outcrop of the Hub seam, about three-quarters of a mile from the town of Glace Bay. The Harbour seam was crossed at 410 feet and the Phalen reached at 867 feet. In 1902 coal hoisting was in full swing.

The mine is worked by the room and pillar system, employs about 1,000 men and boys, and has about 100 horses stabled underground. Pairs of entry levels are driven off directly from the bottom of the shaft 9–18 feet wide, 40–50 feet between pairs, cross-cuts every 50 feet. Pairs of headways are broken off the entry levels 40–50 feet apart, cross-cuts every 50 feet, 400–500 feet between inside headways. These entry levels and headways serve as main haulage ways. Off these headways levels are driven, and off these again are other headways, and off them the rooms. The rooms are 20 to 22 feet wide, but are necked at the mouth, being usually about 12 feet wide for a distance of 30 feet. The pillars between the rooms are about 60–65 feet in width, the rooms being driven every 75 or 80 feet up the headway, the usual number being fifteen on each headway. The back headways and levels are used as air courses and manways, the cross-cuts at first being stopped with single wooden doors covered with tar paper and later by concrete stoppings. These stoppings are generally placed in the middle of the cross-cuts, and are about 6 inches thick The first room is always driven through to the next inside headway for ventilation purposes, and the others to within 80 feet of it.

The rooms are ventilated in the usual manner by means of brattice and brattice doors. The coal is cut both by hand and machines.

The scale of wages for the actual mining of the coal is as follows:—

MACHINE CUT COAL.

Undercutting	11.5c.	per ton	(2240 lbs.)
Shot Firing	10.0c.	"	"
Loading	11.8c	"	"
Deeps	40.5c.	"	"
" 9 feet wide	51.0c.	"	"
Levels	37.5c.	"	"
" 9 feet wide	47.5c.	"	"
Headways	38.5c.	"	"
" 9 feet wide	48.5c	"	"
Cross-cuts, per lineal yard	12.5c.		

HAND CUT COAL.

Rooms	49c.	per ton	(2240 lbs.)
Pillars	46c	"	"
Cross-cuts, per lineal yard	up to 15 feet	25.6c	
	over 15 feet	33.0c.	

The machine used is the "G-3 Harrison" coal mining machine and has given great satisfaction

The coal is undercut a distance of about 6 feet from the face, the mine being about 18 inches high at the face and 5 or 6 inches at the back. Where no shearing is done, three shots are needed, the holes being bored as deep as the mine with either a hand-borer or a Tornado air drill. These holes are generally placed about three-quarter way up the face, and those at the side are bored from anywhere from 2 feet to 1 inch from the rib, according as the coal is gripped or not. The centre hole is slanted toward the high side, and generally has a little more powder. The powder used is "Excellite"—a safety explosive, costing 16c. per lb., and being of the following composition:—

Ammon. Nitrate	80 %—84%
Nitro. Glycer.	7%—9%
Nitro. Cotton	0.5%—1.5%
Wood meal	3.5%—4.5%
De. Nitro	2.5%—3.5%
Castor Oil	0.5%—1.5%
Moisture	0 —2%

The average charge is about 14 oz. per hole, but the amount varies considerably with local conditions. A good machine runner will undercut a couple of rooms, and bore and shoot a crosscut and a room for a day's work, clearing about $5 a day, after paying his helper $2.00.

As mentioned above, some of the rooms are sheared, but until quite recently this was not so. Owing to the fact that the coal produced was very much broken, the Company experimented with several shearing machines of different makes. The trials resulted in the adoption of the type B. Little Hardy shearing machine. This machine is of the ordinary reciprocating air drill type, and strikes about 650 blows a minute.

The machine runner works on contract either at 3 cents per ton for all coal taken from his section, or at 4 cents per ton for all coal taken from his section, from which is deducted all coal taken from narrow work. The men prefer the 4-cent rate. The machine is set up in the most convenient place within range of the face, and the cut is carried as far back as the undercut extends.

As no submarine areas are yet worked in this mine, all the pillars are drawn. The method adopted is to begin by drawing the pillars at the tip of the headway and to work the rest in a series of steps, each pillar towards the level being 50 feet behind the next one higher up. The pillars are attacked from the low side, and if a fall of rock occurs which completely stops work on the face, a crosscut is driven through the pillar about 12 or 15 feet further along, and then the stumps which are left are removed by working back towards the fall.

The robbing is done by hand pick men, who are paid 43 cents a ton. Only the most experienced miners are set at this work, and they are allowed practically a free hand, doing their own timbering, boring and loading, besides the actual mining.

The general method of timbering in the rooms and headways is to set up a prop on each side and to place a boom across them, wedges being driven between the roof and the boom. This timber is unbarked green spruce varying from 4 to 6 inches in diameter, and is loaded into the empty boxes at the pit bottom, each box being supplied with four or five sticks. On an average day from 750 to 800 sticks are sent to the face in this manner. Owing to the varying quality of the roof, it is quite impossible

to give an average spacing of the timber sets. To illustrate this it may be stated that on the north side entry level, from the run around in a distance of about 2,000 feet, not a set of timber has been installed, while the south side deeps, which have only lately been started, had to be abandoned, owing to the impossibility of keeping up the roof with the ordinary timber. The same varying quality of the roof can be found in any set of rooms. In one place where the writer was working, No. 11 room required three props on each side of the track, spaced about 6 or 8 inches apart, with sets 6 inches apart, while in No. 8 room the roof was so good that an ordinary set of timbers, spaced from 6 to 8 feet apart, afforded ample support to the roof. On the motor roads 10 inch by 10 inch squared timber, with the ends set in hitches cut in the coal, have been used. This method is being discarded as the coal crushes, and eventually props have to be resorted to. On some of the motor roads the roof has been brushed, and 12″ x 12″ timber booms are set in hitches in the rock

One noteworthy feature of this mine is the timbering at the pit bottom. Here, on account of the underground dumping system, it is absolutely essential that no delays should be incurred by falls of rock. To obviate this danger 3-foot concrete walls have been built for a distance of over 100 feet on each side of the tipples. Stretching across the road, with their ends resting on these walls, are 24-inch steel I beams, spaced 2 feet, centre to centre.

Although this is not a very gaseous mine the Company insists upon the exclusive use of Ackroyd and Best safety lamps for hand lamps, and instant dismissal is the penalty for taking even a pouch of tobacco inside the fence. Further precaution is observed in the employment of two deputies, whose duty it is to go the rounds of the face twice a day and report upon the amount of gas found at each working face, and also report upon the state of the roof

Owing to the depth of this mine, the workings are so dry that watering is necessary. The air mains are so arranged that they can be filled with water and the water ejected from the end of the pipe at the face by turning on the air. The system seems to the writer to supply a very inadequate protection in the event of a gas explosion, which, though harmless in itself,

or, at most, only locally dangerous, might, if aggravated by the presence of dry coal dust, prove disastrous in the extreme. For instance, the rooms were not watered more than once a week, nor was the water then applied in the form of a spray, the consequence being that in some places the water lay in small pools on the low side, while in others there was no sign of water at all. Again, the writer saw no evidence that water had been applied in the headways or main haulage ways, which were inches deep in excessively fine coal dust. Finally, the timbers and projecting parts of the rib were everywhere thickly covered with impalpably powdered coal which is a source of even greater danger than the dust accumulation on the road bed.

All roadmaking is let by contract, one road-maker being capable of looking after from eight to ten rooms. The road-maker earns from $3.00 to $4.00 per day, being paid 1.7 cents per ton of coal hauled from his section. He has charge of the track up to the face and must maintain the road in good order over his section. When laying new track on old roads, he is paid 14 cents per yard and $1.20 for every turn, whether in new work or not. When rooms have been driven into the third cross-cut, the track is turned up the first room and is laid through the third cross-cut, thus saving much track. The track is 3-foot guage, rails 18 lbs. in rooms; 30 lbs. on levels and 50 lbs. on motor roads. The wages for track laying on motor roads are $2.40 per turn and 28 cents per yard of track. Sleepers are 5-foot dry cedar with a minimum face of 4 inches

Haulage

Horse Haulage.—The coal is hauled from the face to the landings on the levels by horses. Landings are made at the foot of every second headway, the maximum haul being about fourteen hundred feet. The stables are placed in two drifts off the main entry level and at present have stall accommodation for 112 horses, but additional stalls are in course of construction. The stables and pit bottom are lighted by electricity. Four stablemen are employed and are required to report on the condition of the horses when they leave and return to the stables. This precaution was found necessary, since a driver when not

checked might disable his horse when not satisfied with its work, by placing a lump of coal under its collar. The daily fodder allowance is as follows:—

TIME FED.	FOOD.
5 a.m.	5 lbs. cut hay, 5 lbs. chop.
Noon.	4 lbs. oats.
6 p.m.	5 lbs. cut day, 5 lbs. chop.
Midnight	4 lbs. oats.

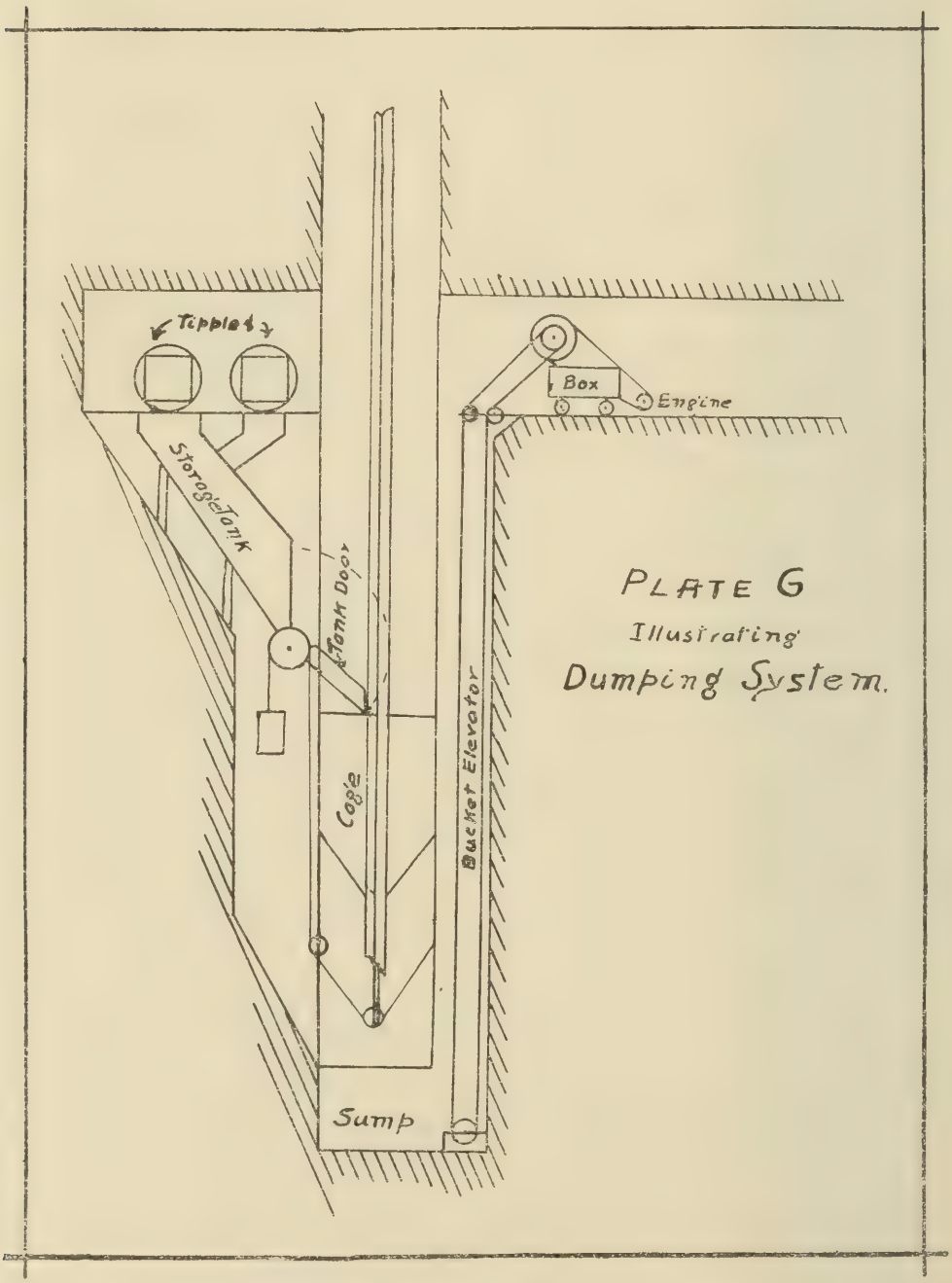
or the equivalent of 28 lbs. per horse per day.

Trip Haulage.—Four double-cylinder, single friction drum, link motion Flory engines of the following dimensions are used for trip haulage:—Cylinders, 14″ diameter and 20″ stroke, 110 H.P.; drum, diameter 66″; length 60″ These engines are placed as follows: one on the south headway, two on Allan's headway, and one on the north deep.

Motor Haulage.—Seven compressed air locomotives, of a weight of from 10 to 20 tons, are in use in this mine.

On No. 1 level off the south side headway, the coal is moved by a motor. There are five headways off this level, with landings at the foot of No. 1 and No. 3. Coal from Nos. 1 and 2 is left at No. 1 landing, and coal from Nos. 3, 4 and 5 is left at No. 3 landing, horses being employed in hauling the coal to these points. The motor conveys the coal from the landings out to the south headway and then couples on to a trip of empty boxes, which it leaves at the landings on the return journey for the next full trip. Motor haulage is also employed on No. 2 level off Allan's headway.

Before describing the hauling of the coal by motors at the pit bottom, a few words are necessary concerning the dumping system. A diagramatic sketch (plate G) is given which illustrates the following explanation. The boxes of coal are run into two rotary tipples at the pit bottom, and the coal is dumped into a storage tank of six tons capacity. The door of this tank is so arranged that when the cage descends it is opened and forms a chute, through which the coal runs into the cage. As the cage rises the door is shut by means of counterweights. When first installed, the door had an automatic catch which was released



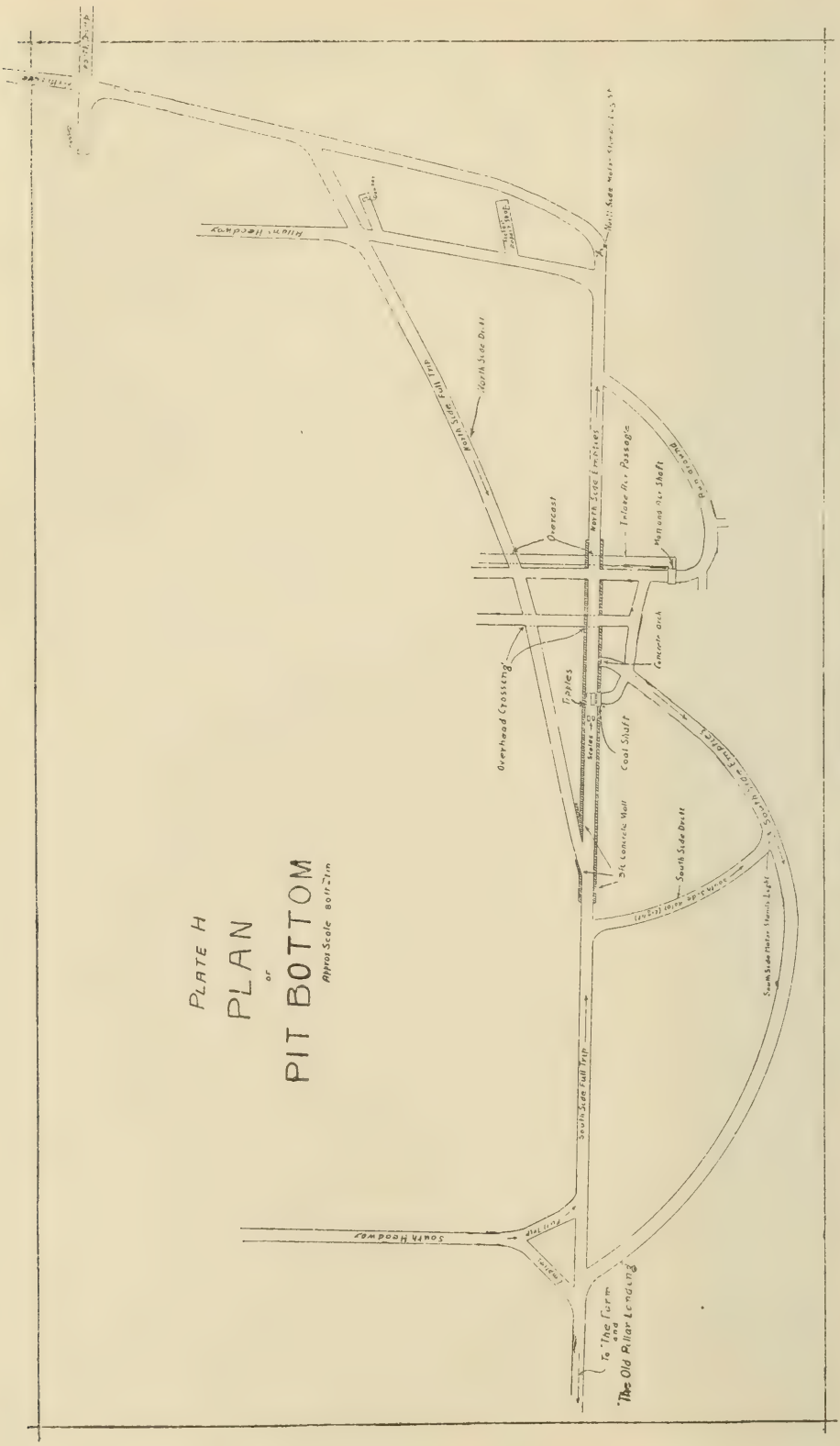
Sketch Illustrating Dumping System.

by the descending cage, but it is now held in place merely by the heavy counterweights. A considerable amount of coal (8 to 10 tons per day) falls below the tanks. This is taken up by means of a bucket elevator, dumped into boxes and again sent to the tipples.

By referring to plate H, the following explanation of the handling of both full and empty boxes at the pit bottom can be easily understood. The motors at the south side run in as far as The Farm, while on the north side they run in to the end of the north entry level.

Taking the south side first:—The motor couples up to a full trip at The Farm and runs out to the bottom, stopping on the way to take on any full boxes at the Old Pillar landing and south headway. The full trip is taken to the scales, and the motor then returns down the south side drift, where it waits at the foot of the cross cut. The south empties, seven at a time, are coupled up and run by gravity to within 25 feet of the waiting motor. The boxes are then all coupled up by the brakeman. The motor there hauls them up the drift into the entry level at the foot of the south headway. What boxes are required are left here and the rest are taken into the Old Pillar landing and The Farm.

On the north side, the motor comes from the north level with a full trip, takes on more full boxes at the Deep and Allan's headway, and then runs down the north drift into the entry level. After backing its load up to the scales, it returns up the drift, runs down the level to the spot marked "X" and there waits for its empties, which come as far as this by gravity. All the empties required for Allan's headway are hauled up to the north drift by the short tail rope haulage, where they are coupled on to the rope from the top of Allan's headway, and so finally reach their destination. The motor is coupled up to the remaining empties and takes them on to the north level, leaving what are required at the north deep. The handling of the coal on the high side of the tipples affords occasion for criticism. The grade on the high side was supposed to be sufficient to run the cars by gravity into the tipples; such is not the case, however, as it is found necessary to employ eight men (at a cost of $30.00 per day) to push the full boxes from the stop-blocks beyond the scales into the tipples. It seems to the writer that the output of the



Plan of Pit Bottom.

mine would fully justify the installation of some mechanical car-handling device.

The water in this mine is pumped to the Harbour seam by means of three Northey pumps of the following dimensions: 20″x 8″ x 24″; 7¼″ x 4½″ x 10″; 7¼″ x 6½″ x 10″. This mine has two shafts, one for coal-hoisting and the other for men and material. The man shaft is divided into two compartments, one for hoisting and the other for air.

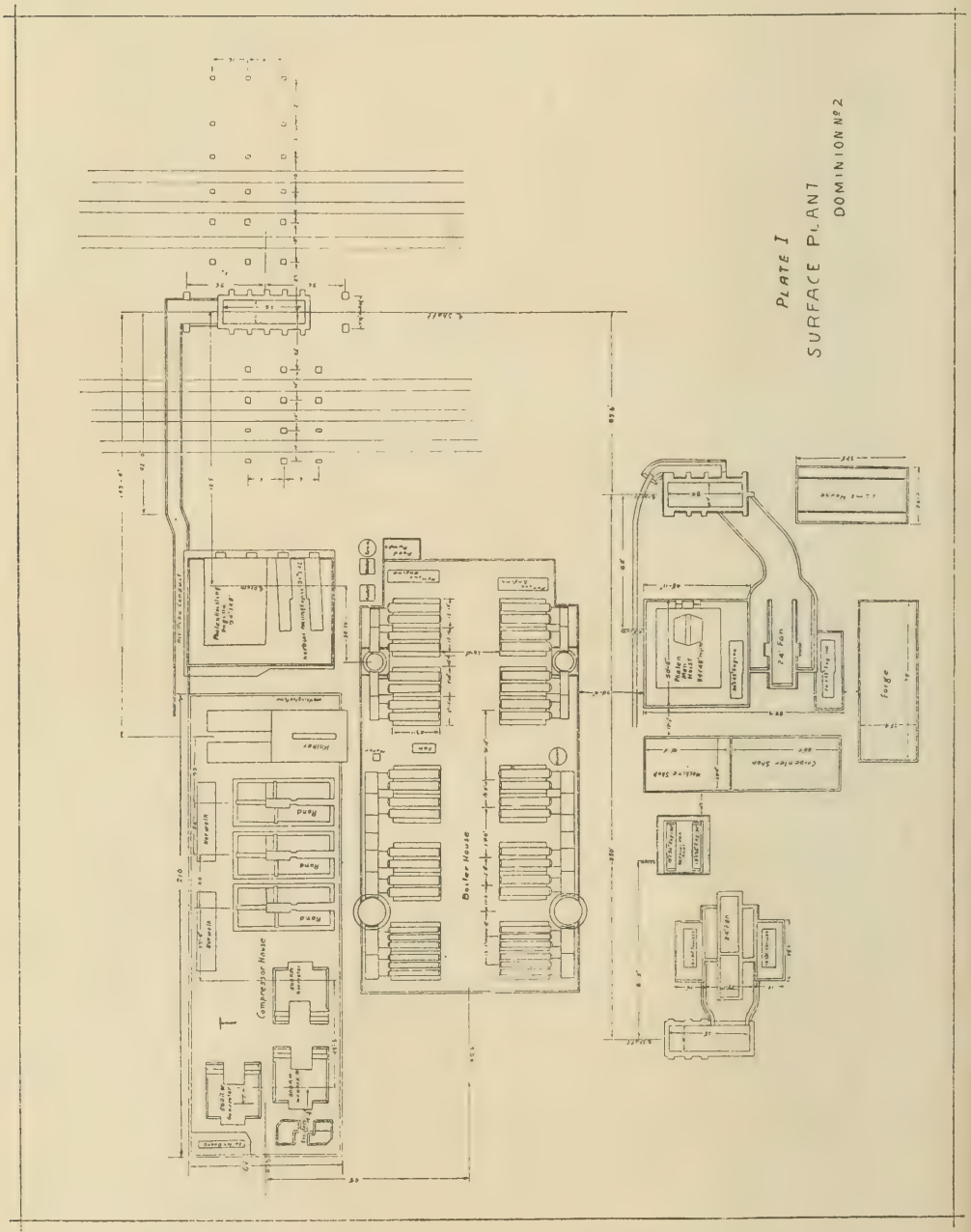
The air is led from the fan house through a concrete passage to its compartment in the man shaft, which is lined with concrete. From the bottom of the shaft the air is carried across the entry levels in an overcast, and is then dispersed through the workings. Both shafts are upcasts for the return air, the warmth of which prevents, to a certain extent, the formation of ice in the shafts during the cold months. The pipe line from the compressor house is carried down one compartment of the coal hoisting shaft.

Plate I shows the lay-out of the surface plant, which supplies the needs of the Phalen and Harbour seams' workings.

Boiler House.

The boiler house contains 20 Babcock and Wilcox boilers, rated at 318 B.H.P. each. Fifteen of these are kept in continuous operation, each being run at 385 B.H.P. Sixteen boilers are fitted with Jones's Underfeed Stokers, three to a boiler, which are handfed at present. The other four boilers are hand-fired. One hundred and ninety tons is the average consumption of coal per 24 hours, No. 9 nut being used during the day, and Hub Slack at night. The four hand-fired boilers are fitted with Parsons' blowers. Forced draught is supplied to the other sixteen boilers by two Sturtevant fans, 8 feet diameter, directly connected to 8¼″ x 10″ Sturtevant engines, running at 305 R.P.M. Draught pressure averages 3.2 inches W.G. An emergency Sturtevant fan, 57 inches diameter, is connected to a C.G.E. motor. The stacks are four in number.

SIZE OF STACK.	DRAUGHT PRESSURE AT FOOT OF STACK,
64′ x 8′diameter	.35″ W.G
75′ x 8′ “	.40” “
75′ x 11′ “	.45″ “
75′ x 10′ “	.45″ “



Plan of Surface Works, Dominion No. 2

1. Boiler House
2. Compressor Building
3. Pit Head and Surface Plant

The water used in the boilers comes from near Port Morien. It is pre-heated in two Webster "Star Vacuum" feed heaters, and is pumped into the boilers by four 12″ x 10″ x 6″ Knowles pumps.

The Air Compressing and Central Electric Plants are in the one building. The air compressing plant consists of the following machines: Three compound Rand compressors—cylinders, H.P. steam, 20″; L.P. steam 36″; H.P. air 20″: L.P. air 32″; stroke 48″; Flywheel 18 feet diameter. Weight, 18 tons. Capacity of each, 3,574 cu. feet per minute when running at 65 R.P.M. I.H.P., 550.

One compound Walker compressor: Cylinders: H.P. steam, 31″; L.P. steam, 57″; H.P. air, 32″; L.P. air, 51″; stroke, 60″. Fly-wheel, 20 feet diameter. Weight 30 tons. At 45 R. P. M. its I.H.P. is 1,200. Capacity at above rate of working is about 6,400 cu. feet per minute.

Two Norwalk straight line, three-stage compressors: Cylinders: H.P. steam, 20″; L.P. steam, 41″; H.P. air, 8″; I.P. air, 16″; L.P. air, 28″. Pressures: L.P., 40 lbs. per sq. inch. I.P., 80 lbs. per sq. inch. H.P., 900 lbs. per sq. inch. Capacity at 65 R.P.M. is about 680 cu. feet per minute. I.H.P. at above rate of working is about 550.

The steam pipe line is provided with wells, from which the water is pumped back to the boilers by a 4″ x 6″ x 10″ Knowles pump.

All the machines in the building are oiled automatically, the oil being stored in two 200-gallon tanks having a 15-foot head. All the oil drippings are filtered and pumped back to the storage tanks by a 3″ x 2″ x 3″ Knowles pump.

The central electric plant comprises: three Westinghouse 550 K.W. alternators, 25 cycle, 3 phase, 125 R.P.M., 6,600 volts. These are directly connceted to compound Goldie-McCulloch engines: Cylinders: H.P. 20″; L.P. 40″; stroke 26″; fly-wheel, 14 feet diameter, 30 tons in weight; I.H.P., 700. Two 75 K.W. Westinghouse exciters directly connected to 12″ x 12″ Goldie-McCulloch Ideal engines, 500 R.P.M.

The writer is informed that a contract has been let to the Daniel Adamson Co., of Manchester, England, for the installation of an exhaust steam turbine. It will be of the Rateau type, with

barometric jet condenser. The exhaust steam available will be in the neighbourhood of 100,000 lbs. per hour. The turbine will operate a 1,000 K.W. generator, and will be erected at the spot marked "T" on plate I.

The Phalen coal hoist is a 34″ x 48″ horizontal slide valve engine, made by the Dixon Company. The present double conical drum was installed in 1908 by the Jenckes Company. It is of the following dimensions: large diameter, 18′; small diameter 10′ 4″; width across the face, 5′ 7″. The I.H.P. of the hoist is about 1,800.

The average length of time taken for one hoist is 25 seconds. The rope is $1\frac{5}{8}$ inches in diameter, 6 strands, 26 wires per strand, 1,320 feet long, made by Latch & Batchellor. The Phalen man hoist is of the same style and size as the coal hoist. The time of a descent is 40 seconds.

The Phalen workings are ventilated by a Walker fan, having a capacity of 350,000 cu. feet of air per minute at 3 inch W.G. It is 24 feet in diameter and is directly connected to two 24″ x 42″ Dixon engines running at 94 R.P.M. It is at present supplying 250,000 cu. feet of air per minute to the mine.

The bankhead is a large steel structure, 120 feet high, built on concrete foundations and covered with corrugated sheet iron. The coal is screened in the bankhead, and a new screening plant is being erected in which better work is to be done.

The main shaft is divided into five compartments, two for Phalen and two for the Harbour Coal hoisting, and one for the pipe line.

The lamp house is 52 feet long by 26 feet wide, and is equipped with the most up-to-date lamp cleaning and lighting apparatus.

The No. 2 wash house is 120 feet long by 30 feet wide, and contains about 600 lockers.

The writer worked in this mine for a period of two months during the summer of 1909, and except where otherwise noted, obtained the above information at first hand.

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